Fundamentals of Robotics

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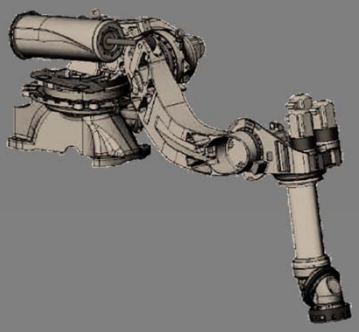
Food & Packaging Industry Specialist

Stäubli Robotics



The Business Case for Robotics and Automation Dollars
Robots and the Robotics Industry
Robot and System Technology
Applications

Robotics = Flexible Automation

Robots are integral to Lean manufacturing

- **Manual**
  - Fast product change
  - Breaks
  - Monotonous tasks
  - Health Claims
  - Labor Issues
  - Training
- **Hard Automation**
  - High Volume
  - Requires Set-up time
  - More maintenance
  - Air Cylinders / actuators
  - Rigid conveyors / fixtures
- **Flexible Automation**
  - Quick product change
  - Programmable
  - Repeatable
  - Changeable Cell configuration
  - Responds to Part Changes

Robot Definitions

- **Dictionary**
  - "An automatic apparatus or device that performs functions normally ascribed to a human or a machine in the form of a human."
- **Robotic Industries Association (RIA)**
  - "A reprogrammable multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks."
- **Robota**
  - Czech word for "forced labor" or "serf"

Why Automate – reasons to spend

Buy a Robot and Save America

Buy a Robot and Save America

- 2 shifts per day material handling for 20 years (80,000 hours)
  - 30 Kg Size – 5.4 kVA rating
    - Electric rates 0.11 KwH = 0.594 cents per hour
  - Maintenance Costs for 80,000 hours
    - 10,000 hour Lubrication – Lube 6 times
      - Year 3 about $500 in lubrication costs
      - Year 6 another $500 in Lubrication costs
      - Year 9 another $500 in Lubrication costs
    - 8 – 10 Years expect some form of unscheduled maintenance
      - $5,000 from typical Service Life Cycle Costs
    - Well after 10 years refurbishment may be required
      - Typical cost for full refurbishment - $10,000

Do The Math

- *2 shifts / day for 20 Years*
  - *Rebuild once in 20 years……$10,000*
  - *Maintenance for 20 years……$13,000*
    - *Lubrication……..$3,000*
    - *Unscheduled repairs…..$10,000*
  - *Power 0.59 x 80,000 hours……..$47,200*
  - *Total …… $70,200*

- *OR do it Manually.*
  - *80,000 hours x $30.00…… $2,400,000*

Savings…… $2,329,800

Buy a Robot and Save America

- **Back to the article in Forbes Magazine "Buy a Robot and Save America"**
  - **Average wage for an unskilled worker is $15 - $20 per hour plus benefits**
  - **Average UAW wage for unskilled trades is $30 - $35 per hour plus benefits**
  - **Average wage for similar labor in China is $3 per hour plus benefits(?).**
  - **Average wage for a robot is under $1 per hour with no benefits.**

THIS IS THE BUSINESS CASE FOR ROBOTICS!

Justification

Press Line - Manual Process

- **Maximum Throughput**
  - **53 seconds total cycle time**
  - **Per press net yield of 68 pieces per hour**
- **One operator per press / shift – 3 shifts / day**
- **Six presses in operation = 7 Operators / Shift**
- **Labor rate of $12.00 per man-hour = $15.00 burdened**
  - **$105 per hour**
- **Labor Cost per part = $1.54**
- **Yearly labor cost = $655,200**

Press Line Justification

Press Line - Robotic Process

- Maximum Throughput
  - 10 seconds total cycle time
  - Per press net yield of 360 pieces per hour
- One to one and half operators for entire line
- Six presses in operation = 1.5 Operators / Shift
- Labor rate of $12.00 per man-hour = $15.00 burdened
  - $22.5 per hour
- Labor Cost per part - $0.63
- Yearly labor cost = $140,400

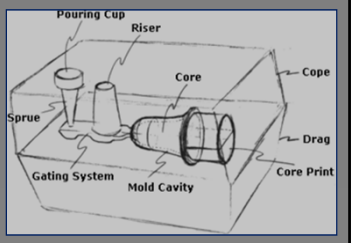
Complete Analysis

- Direct labor reduction
  - reallocation of 5.5 operators per shift
- Direct labor savings of $518,800 per year
- 81% throughput improvement
  - 53 seconds versus 10 seconds
- 41% reduction in direct labor cost per piece
- $0.63 versus $1.54

Total investment for automating six presses:	*$1,050,000*
Total direct labor savings:	*$518,800*
Payback period (from direct labor alone):	*24 months*
Increased press capacity of:	*81%*
Part Cost Savings	*$0.91*

The Green Sand Casting Process

- Green Sand Casting Process
  - Create the mold
    - mixture of sand, clay and moisture
    - simple materials
    - materials can be reused or regenerated
    - low cost materials
  - Pour molten metal into the molds
  - Remove the parts
  - Machining or clean up is required
- Green Sand Cast Parts
  - Require surface finish
  - Lowest cost casting process
- Labor intensive process
  - Automated mold creating
  - Hand Pouring
  - Manual parts removal



[redacted]

Robotic Pouring

- Customer's Results
  - Four times the manual capacity
    - Impeded by peripheral equipment
    - One part every 30 seconds
  - Reduced labor by three per shift
  - Energy reduction
    - automatic furnace lid closure provides insulation
  - Operator Safety is vastly improved
  - Reduced material use
    - same quantity for every part
  - Parts consistency is 100%
    - repeatable process
  - Increased Parts Quality
    - metal heat more consistent
    - pour efficiency

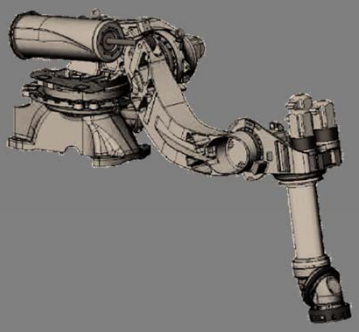
[redacted]

Typical Performance

- **2 - JS10 - Kg Robots**
  - First Installed in 1991
    - Ran 5 second cycle time 3 shifts / day until 2003
  - Re Installed in 2005 (75% capacity)
    - Ran 10 second cycle time 3 shifts / day
  - Both retired in 2008 due to line reconfiguration
- **2 - JS10 - 10 Kg Robots**
  - First installed in 1992
    - Ran 5 second cycle time 3 shifts / day until 2005
  - Reinstalled in late 2005 (75% capacity)
    - Ran 10 second cycle time 3 shifts / day
  - One retired late 2008 due to wiring harness failure
  - Second one is retired 2009
- **3 FS10E - 10 Kg Robots**
  - First Installed in 2008
  - Replacement for the JS10's
  - Run a 4 second cycle time
  - Almost 20,000,000 cycles to date
  - Over 25,000 hours

58,900,000 cycles
93,600 hours

73,000,000 cycles
110,000 hours



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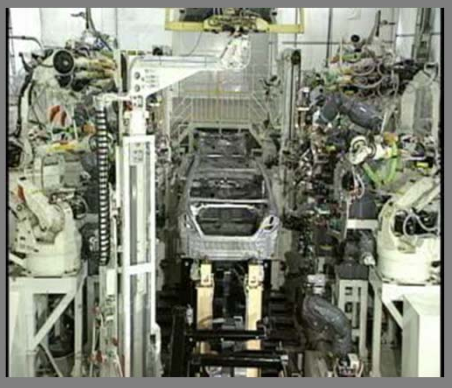
Industrial Robotics History

- History
  - 1956 - Unimation
    - George Devol & Joseph Engleberger met
    - First Working Model late 1956
  - 1961
    - Patented
    - First Installation - GM Lordstown, OH
      - Die Cast Part Extractor
  - Unimate Robot
    - First Industrial Robot
    - 4000# Arm
    - Step by Step Commands stored on a magnetic drum
    - Hydraulic Actuators
    - $100,000 Plus Price
- Original Model
  - In Smithsonian Institute
  - Hundreds still in operation today

Robot Industry - 2013

- Globally
  - Over 850,000 at work today
  - Over 100,000 sold per year
  - $5,000,000,000 - robots
  - $15,000,000,000 - systems
- North America
  - Over 230,000 installed
  - Growth rate as high as 20% yearly
    - 2008 / 2009
    - 2013 Setting new records
- Largest Users
  - Automotive - 47%
  - Electronic -15%
- Major Applications
  - Material Handling - 39%
  - Welding - 30%
  - Assembly - 8%



Only about 10% of the US companies that could benefit from robots have installed any so for

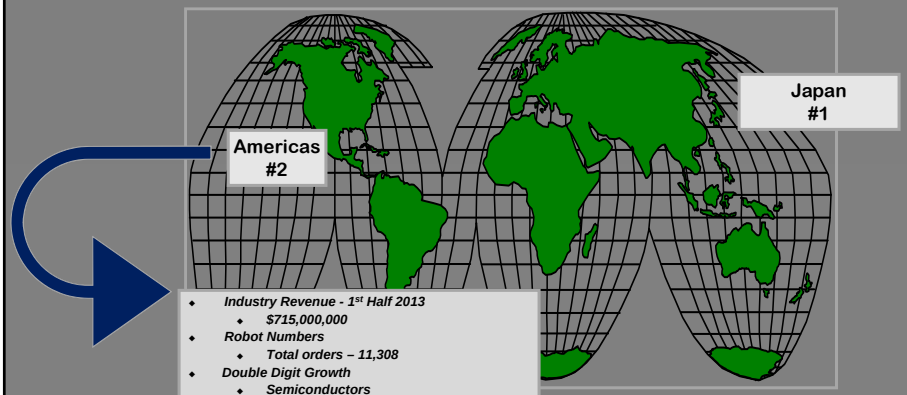
Robotics Industry Players

- Robot Manufacturers
  - Manufactures the robot
  - Provides robot training, maintenance and service
- System Integrator [System Builder]
  - Integrate the robot into a system to perform a specified task
    - Independent business, industry specific, allegiance to robot manufacturer
    - Has knowledge of End User's business
  - Provides system components, installation, training, service and support
    - Design and build the robot based system
    - Purchases robot and all peripheral equipment
    - Designs and builds systems, writes and maintains programs
    - Trained on entire cell / provides training on system
- End Users
  - Uses the robotic based system in production or processing
  - Knows what is required to accomplish tasks
  - Ultimate user - needs training, service, maintenance, spare parts

Robot Manufacturers Today

STÄUBLI
Kawasaki Kawasaki Robotics (USA), Inc.
adept
DENSO Robotics
Columbia okura LLC
YASKAWA
ABB
COMAU ROBOTICS
EPSON Robots The Power of Choice
PAR SYSTEMS
NACHI NACHI ROBOTIC SYSTEMS INC.
reis REIS ROBOTICS
FANUC Robotics
MITSUBISHI ELECTRIC
KUKA
CLOOS
OTC DAIHEN Inc.
YAMAHA

Worldwide Distribution



- *Industry Revenue - 1st Half 2013*
  - *$715,000,000*
- *Robot Numbers*
  - *Total orders – 11,308*
- *Double Digit Growth*
  - *Semiconductors*
  - *Food & Consumer Goods*
  - *Life Sciences*

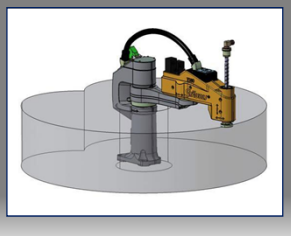
Traditional Applications defined by the RIA

- Spot Welding
- Arc Welding
- Coating & Dispensing
  - Less than 10 pounds
  - Greater than 10 pounds
- Assembly
  - Less than 10 pounds
  - Greater than 10 pounds
- Material Handling
  - Packaging / Palletizing
  - Machine Tending
  - Body Shop
  - Other Material Handling
- Material Removal
- Inspection

Defined by Robotics Industry Association
www.robotics.org

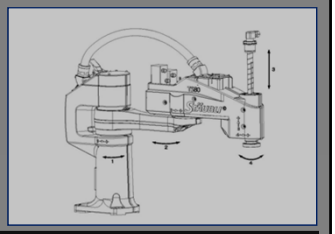
General Terminology

- Work Envelope, Work Space or Reach
  - Range of Motion (mm)
  - The set of points representing the maximum extent or reach of the robot hand or working tool in all directions. Also referred to as the working envelope or robot operating envelope.
- Payload
  - Weight carrying capacity (Kg)
  - The maximum total weight that can be applied to the end of the robot arm without a sacrifice of any of the applicable published specifications of the robot.
- Cycle Time or Speed
  - Execution time for one task
- Additional Specs
  - Torque / Inertia



The Axes – Degrees of Freedom

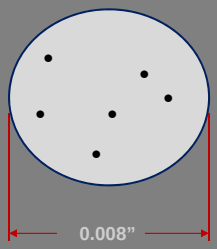
- Degrees of Freedom - Axes
  - One of a limited number of ways in which a robot joint may move.
- Joint 1 - Base Rotation
- Joint 2 - Rotation of the lower arm
- Joint 3 - Rotation the upper arm
- Joint 4 - Swivel of the upper arm
- Joint 5 - Bend of the wrist
- Joint 6 - Rotation of tool mounting plate
- Joint 7 - ??? – External Axes



Repeatability

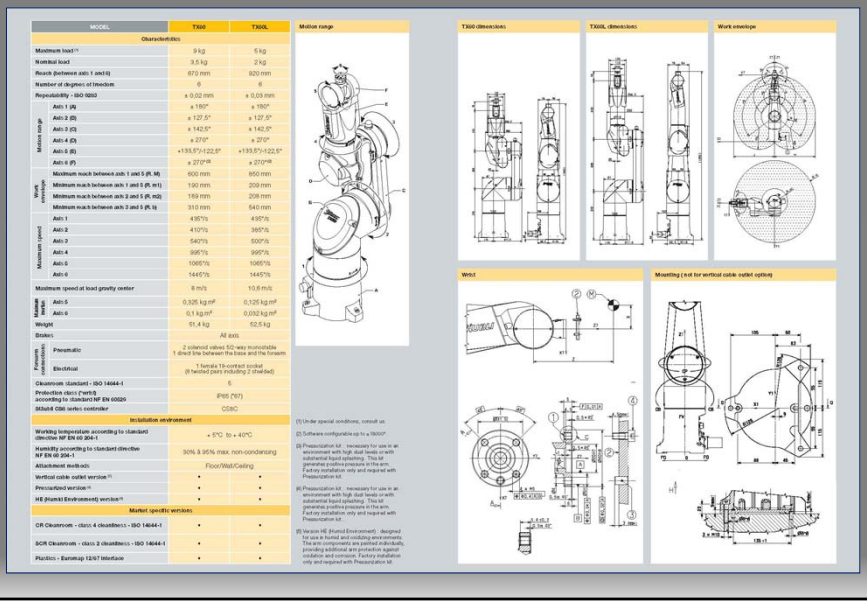
- **Repeatability**
  - **Ability of the robot to return to a preprogrammed position.**
  - **Closeness of agreement of repeated position movements under the same conditions to the same location.**

Assume repeatability to be +/- 0.004”



Robot can position anywhere within the 0.008” diameter circle and still fall within its repeatability specification.

Typical Specifications



MODEL	TX60	TX60L
Characteristics		
Maximum load [1]	9 kg	5 kg
Nominal load	3.5 kg	2 kg
Reach (between axis 1 and 6)	670 mm	920 mm
Number of degrees of freedom	6	6
Repeatability - ISO 9283	± 0.02 mm	± 0.03 mm
Motion range: Axis 1 (A)	± 180°	± 180°
Axis 2 (B)	± 127.5°	± 127.5°
Axis 3 (C)	± 142.5°	± 142.5°
Axis 4 (D)	± 270°	± 270°
Axis 5 (E)	+133.5°/-122.5°	+133.5°/-122.5°
Axis 6 (F)	± 270° [2]	± 270° [2]
Work envelope: Maximum reach between axis 1 and 5 (R, M)	600 mm	850 mm
Minimum reach between axis 1 and 5 (R, m1)	190 mm	209 mm
Minimum reach between axis 2 and 5 (R, m2)	189 mm	208 mm
Minimum reach between axis 3 and 5 (R, i)	310 mm	540 mm
Maximum speed: Axis 1	495°/s	495°/s
Axis 2	410°/s	360°/s
Axis 3	540°/s	500°/s
Axis 4	995°/s	995°/s
Axis 5	1065°/s	1065°/s
Axis 6	1445°/s	1445°/s
Maximum speed at load gravity center	8 m/s	10.8 m/s
Admissible inertia: Axis 5	0.325 kg.m²	0.125 kg.m²
Axis 6	0.1 kg.m²	0.032 kg.m²
Weight	51.4 kg	52.5 kg
Brakes	All axis	
Fluxus connections: Pneumatic	2 solenoid valves 5/2-way monostable 1 direct line between the base and the forearm	
Electrical	1 female 19-contact socket (9 twisted pairs including 2 shielded)	
Cleanroom standard - ISO 14644-1	6	
Protection class ("wrist") according to standard NF EN 60529	IP65 ("67")	
Stäubli CS9 series controller	CS9C	
Installation environment		
Working temperature according to standard directive NF EN 60 204-1	+ 5°C to + 40°C	
Humidity according to standard directive NF EN 60 204-1	30% à 95% max. non-condensing	
Attachment methods	Floor/Wall/Ceiling	
Vertical cable outlet version [3]	•	•
Pressurized version [4]	•	•
HE (Humid Environment) version [5]	•	•
Market specific versions		
CR Cleanroom - class 4 cleanliness - ISO 14644-1	•	•
SCR Cleanroom - class 3 cleanliness - ISO 14644-1	•	•
Plastics - Euromap 12/67 interface	•	•

Motion range

TX60 dimensions

TX60L dimensions

Work envelope

Wrist

Mounting (not for vertical cable outlet option)

(1) Under special conditions, consult us.

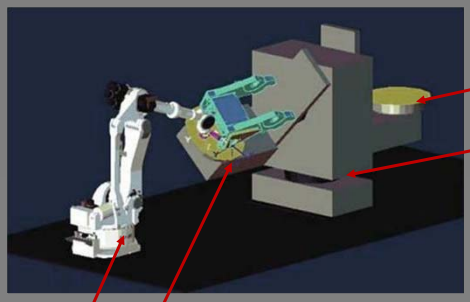
(2) Software configurable up to ± 180°

(3) Pressurization kit : necessary for use in an environment with high dust levels or with substantial liquid splashing. This kit generates positive pressure in the arm. Factory installation only and required with Pressurization kit.

(4) Pressurization kit : necessary for use in an environment with high dust levels or with substantial liquid splashing. This kit generates positive pressure in the arm. Factory installation only and required with Pressurization kit.

(5) Version HE (Humid Environment) : designed for use in humid and oxidizing environments. The arm components are painted individually, providing additional arm protection against oxidation and corrosion. Factory installation only and required with Pressurization kit.

External Axes / Coordinated Motion

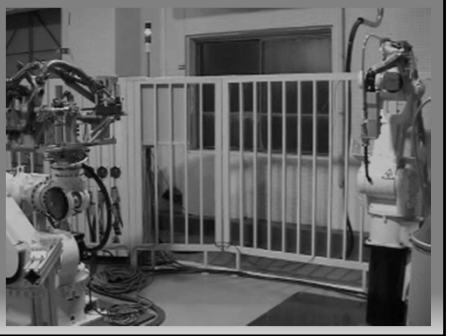


Axis 10 and 11 – Part Spinners

Axis 7 - Turntable

Axis 8 and 9 – Sky Hooks

Axis 1 to 6 - Robot



Common Industrial Robots

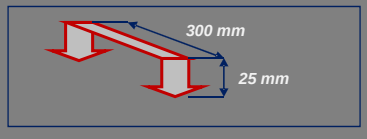
- Cartesian / Gantry
- SCARA
- Telescopic
- Delta Class
- Fast Picker
- Snakes
- Paint Specific
- Articulated
- AGV
- Modular

Cartesian / Gantry Robots

- Four Plus Axes
- Simple Motions
  - Linear X, Y, Z
  - Tool Rotation
- Components
  - Base / Superstructure
  - Arm / Runway
  - Telescope / Carriage
  - Controls

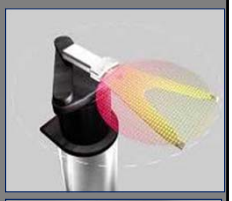
SCARA Robots

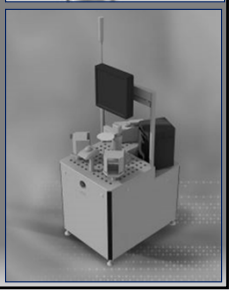
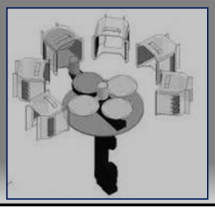
- Four Degrees of Freedom
  - Advanced Control
  - One Linear Axis and Multiple Rotary Axes
- Motions
  - Rotational
  - Linear Z Axis
- Highly Accurate
  - ± 0.01 mm
- Fast and Vibration Free
  - Adept Cycle: 0.30 – 0.35 seconds



Telescopic Robots

- *Usually exclusive to Semi Conductor Applications*
- *3, 4 and 5 axis designs*
- *Clean Room applications*
- *Specific to Application*
  - *Wafer Handling*
  - *Flat Panel Screens – larger robots*



"Delta" Class Robots

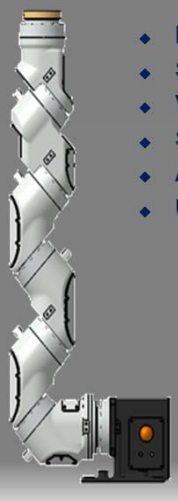
- **3 Axes – Tripod / 4th is optional spin**
  - **Very stiff**
- **Sorting and Picking**
  - **Higher level vision required**
  - **Conveyor Tracking function**
- **Low Payloads**
- **Pick and Place / Sorting**



Fast Picker Technology

- **High Speed Pick and Place**
  - **200 Picks per minute**
  - **Highly Accurate**
  - **Very stiff**
- **Sorting and Picking**
  - **Vision is typically required**
  - **Conveyor Tracking function**
- **Low payload**

"Snake" Robots



- **Multiple Axes**
- **Stack of Servo Motors**
- **Versatile**
- **Slim Shape**
- **Advanced Freedom of Movement**
- **Uncommon outside of Automotive applications**

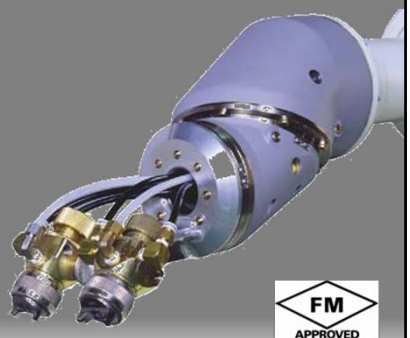
Articulated Robots

- 4, 5 or 6 Axis Designs
  - Rotational Motions
- Most Common / Most Flexible
- 3 Kg to 1000 Kg Payload



Paint Robots

- 6 Axis Articulated
  - Designed for Intrinsically Safe Environment
  - Hazardous Areas
- Different Wrists
- Different Motion and Movement
- Specific to Paint

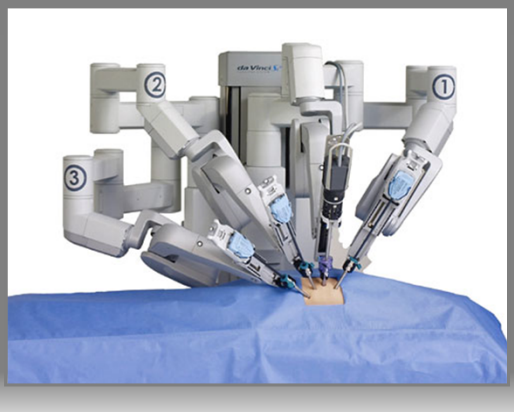



AGV's

- Automated Guided Vehicle
  - Floor Markers
  - Vision or Lasers
- Material Movement

Modular Robots

- System with a combination of robot types
- Multiple Axes



Specialty Industrial Robots

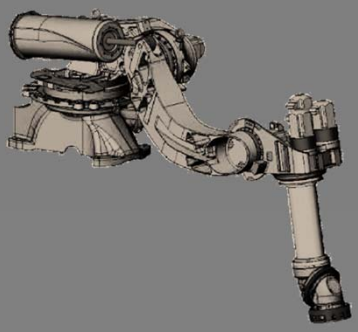
Modifications to the base design

- Clean Room
- Machining
- Food Grade
- Wash Down
- Sterile
- Stainless Steel

New Applications and Markets

- Service Industry
  - Food Service – RoboBar
  - Care for the Elderly
  - Emergency Service - Humanoids
- Medical and Pharmaceutical Industries
  - Prescription Dispensers
  - Hair Restoration
  - Surgery System or Doctor Guidance
  - Prosthetics Research and Design
- Steel Industry
- Food and Beverage
- Entertainment
- Warehousing

Beyond Industrial Robots?



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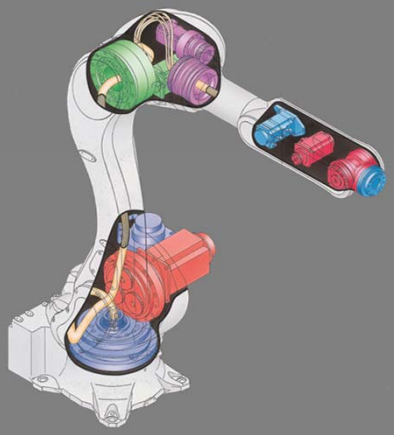
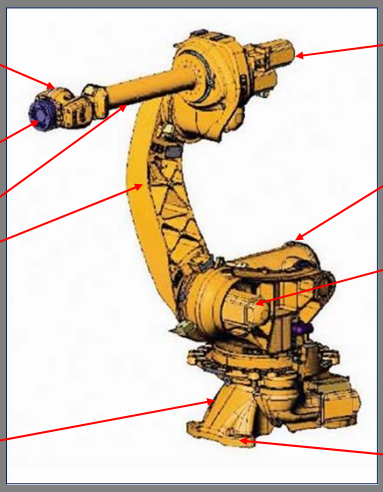
Robot Components

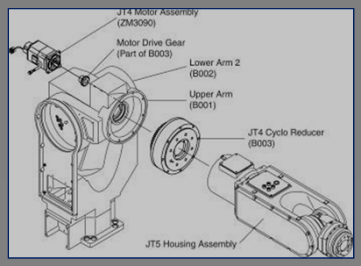
Arm and Controller

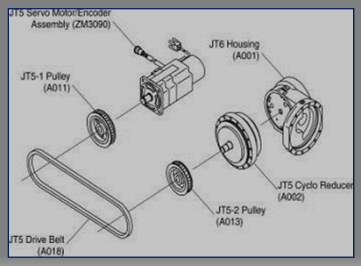


Robot Arm or Manipulator



Drive System





- Design
  - Belt or Direct Drive
- Components
  - Brushless AC Servomotors
  - Absolute Encoders / Resolvers
  - Gears
  - Couplings
  - Timing Belts
  - Drives
  - Castings
- Maintenance
  - None
  - Lubrication

15 Minute Mean Time to Repair

Robot Installation and Mounting

- Installation
  - Floor, Ceiling or Wall
  - Direct to Floor or use a Riser
  - Common Base for Systems
- Proper Fasteners / No Casters
- Tracks

Robot Environment

- **Typical Environmental Specifications**
  - **IP54 / 65 / 67 Standard**
  - **Ambient Temperature: 0 – 52 ^{o}C**
  - **Relative Humidity: 35% - 85% Non Condensing**
  - **Vibration: less than 0.5 G**
- **Optional**
  - **Clean Room**
  - **Wash Down**
  - **Freezer**
  - **Sterile**
- **Intrinsically Safe / Hazardous Duty Units**
  - **Typically for Spray Painting**
  - **Explosion Proof Applications**

Outside Typical Environmental Specs?

- ***Protection is required***
  - ***Covers***
    - ***Basic drapes for dirt protection***
    - ***Water resistance***
    - ***Cooled / Heated***
    - ***Acid Resistant***
    - ***Air Purged***
  - ***Other Protection***
    - ***Heat Shields***
    - ***Water Cooling***
    - ***Air Purged***

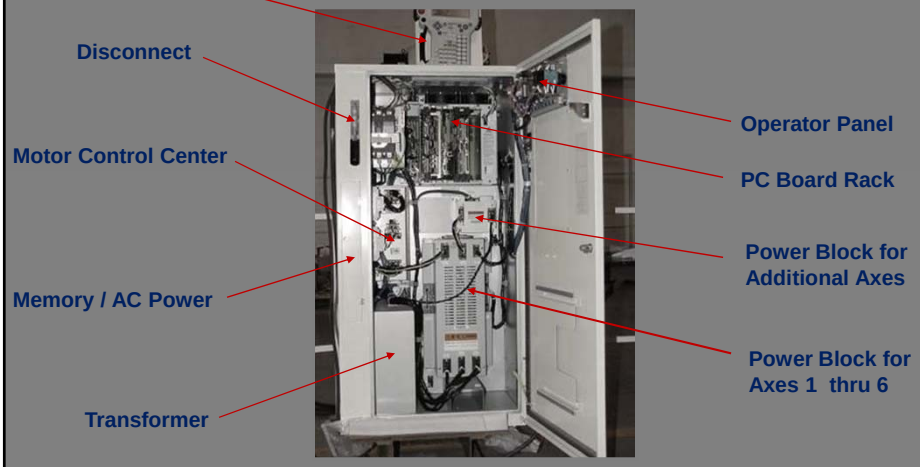
Robot Controllers

- *Robot Components*
  - *Controller*
  - *Teach Pendant*
  - *Multi Controllers*
- *System Control*
  - *PLC*
  - *PC*

Controller

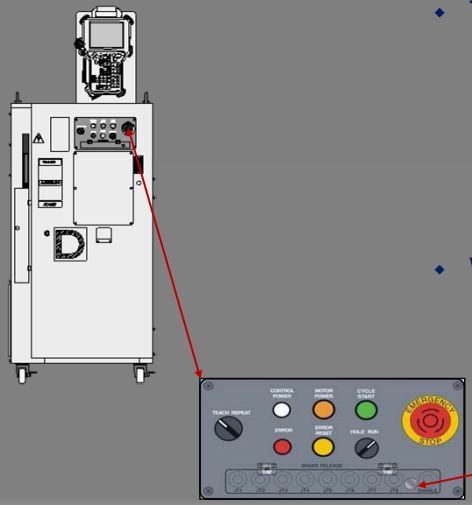
- **Design**
  - **Houses Servo Amplifiers**
  - **Houses Signal Amplifiers**
  - **Houses Power Blocks**
  - **Houses Programmable Controller**
  - **Teach Pendant connects to the Controller**
- **Functions**
  - **Robot Motion - Drives motors**
    - **Coordinates all axes to control the Tool Center Point**
  - **Controls I/O**
    - **Digital**
    - **Analog in / out**
    - **Fieldbus**
  - **Communicates with production system**
  - **Modifies tasks per input or instruction**
  - **Networks**
  - **Collects Data**
  - **Maintenance Monitoring**

Typical Controller Components



15 Minute Mean Time to Repair

The Operator's Panel



- The Operator's Panel
  - Apply motor power
  - Cycle start programs
  - Hold or stop programs
  - Select modes of operation
  - Reset errors
  - Determine motor power status
  - Determine error status
  - E – Stop
- Working Mode Box
  - Provides functions when the controller is rack mounted

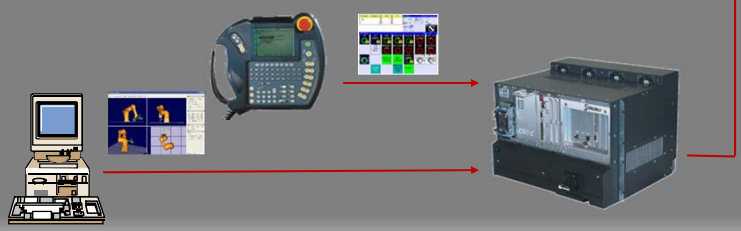
Break release switches are used to manually release the axes brakes with motor power OFF.

Teach Pendant

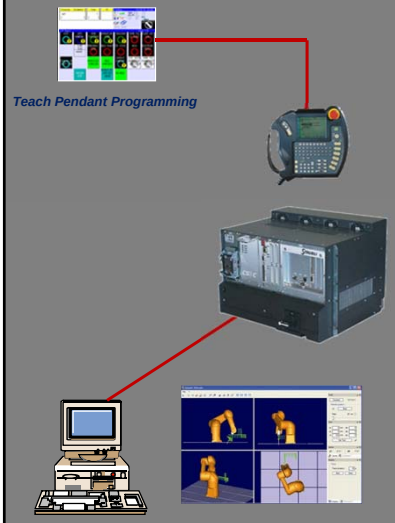
- Design
  - Hand Held
  - LCD Display
  - Hard keys for Functions / Keyboard
- Functions
  - Communicates with Controller
  - Dead man Switches
  - E - Stop
  - User's Interface to the Controller
    - Monitor
    - Teaching / Programming
  - Operator's System Interface Possibility

Programming

- *Programming*
  - *Developing the set of instructions that causes the robot to execute a specific task. Can be performed on-line or off-line.*
- *Teaching*
  - *To move a robot through a series of points to be stored in memory for the robot to perform its intended task. Teaching is typically performed on-line by means of a teach pendant.*



Teaching / Programming Methods



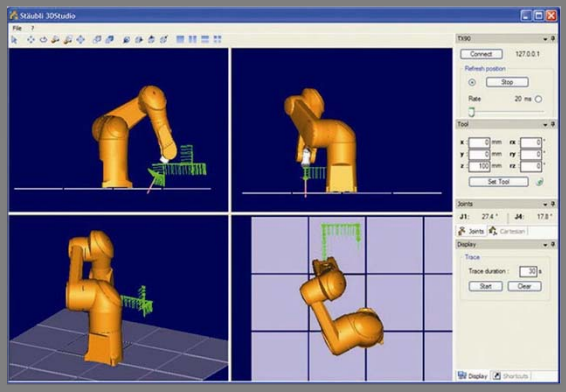
Teach Pendant Programming

PC Programming

- *Teach Pendant*
  - *Programmer holds the teach pendant*
  - *Manually teaches the robot*
- *Off Line Programming*
  - *Program written remotely*
  - *Higher level language*
  - *Loaded into Robot Controller*
  - *Touch up required*
  - *No additional hardware is needed.*
- *Program Storage*
  - *USB*
  - *Other media*
- *Check Programs*
  - *Slow speed operation*

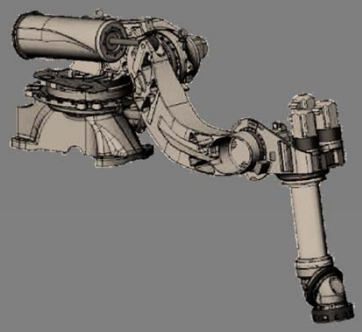
Robot System Software

- **Simulation and Off Line Packages**
- **Graphical / GUI Overlay**
- **Soft Absorber**
- **Cooperative Motion**
- **Application Specific**
  - **Palletizing**
  - **Welding**
  - **Dispensing**
  - **Tracking**
  - **Tending**
  - **Paint**
- **Operator Interface**
- **Maintenance Log**
- **Line Balancing**
- **Help Function or Users Manuals**
  - **Customizable**



Basic Robot Motion Teaching

- Define Tool Center Point
- Motion Instruction
  - Defines a target position
- Interpolation Instruction
  - Defines how to get to the position
  - Joint Move - Robot articulates any axis to accomplish the move
  - Linear Move - Maintains the tool in the orientation specified
  - Circular Move - Three points and a radius to scribe a circle
- Speed
  - Expressed in percent of full speed or a software set maximum speed
- Termination Instruction
  - Expressed as a number [1 - 9] most to least accurate.
  - Defines approach to the target position
- Additional Programming Activities
  - Actions to be complete before moving to the next target position
    - I / O switching
    - Data acquisition



The Business Case for Robotics and Automation Dollars
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Applications

General Thoughts

- *Robots are a Mature Product*
  - *Pre-engineered / production devices*
    - *Various models to choose from*
  - *Very little customization at the robot level*
  - *Repeatable*
    - *Must have methods to deal with random events*
  - *Programmability provides the flexibility*
- *Systems*
  - *Some are Mature Products*
  - *Building blocks for designs*
  - *Many are Custom Designs*

Industrial Robot Systems Components

- **System Components**
  - **Robot and Controller**
  - **Arm Dressing and Risers**
  - **End of Arm Tooling**
  - **Parts Fixtures or Locators**
  - **Interfaces**
  - **Pneumatics**
  - **Sensors**
  - **Electrical Components**
  - **Cables**
  - **Peripheral Equipment**
    - **Varies by application**
  - **PLC or External Control**
    - **Communication via Network or Discrete I/O**
  - **Safety Components**
    - **Fence, Gates, Interlocks, Light Curtains, Barriers, Awareness Beacons**

The robot arm is only part of your robotic solution. End of arm tooling, industrial fieldbus systems, simulation and software are among the issues critical to the success of your robotic system.

Industrial Robot Systems Components

Arm Dressing

Robot

Tooling

Robot Riser

System Controller

Robot Controller

Safety Fence

System Development Process

- Recognize the need
  - Determine that Robotics are an Applicable solution
- Identify the System Specifications
  - What do you want to do?
    - Existing Process, Reach, Payload, Speed, Operator Involvement, QC Issues, Interface with Production System, Technological Capability of User
  - Who is going to Integrate the system?
    - End user, Integrator, Robot Manufacturer, Combination
- System Design and Build
  - Preliminary Layouts and Design Proposal
    - Space Required, Parts Movement, Tooling, Safety Concerns, I/O, Interfaces and Communication, Operator Involvement
  - Simulations / Cycle Time Study / Verification Tests
  - Build, Test and Run Off the system prior to shipment
- System Start Up and Commissioning
  - Installation, Start-up and Customer Acceptance
  - Continuous Improvement

Involve all parties that will interface with the system in the development process to assure acceptance when the system arrives in your facility

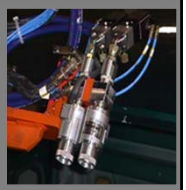
Selecting a Systems Integrator

- Determine if the Integrator has experience in your industry
  - Transferable knowledge
- Evaluate the Integrator's background and capabilities
  - Full Service
  - Commercial Issues
- Check references
  - The Integrator's
  - Robot Manufacturers
- Prepare for disaster
  - What happens?
- After sale maintenance
  - Integrator
  - Robot manufacturer
- Cost
  - Is the lowest bid the best?

Tooling / End Effectors / E.O.A.T

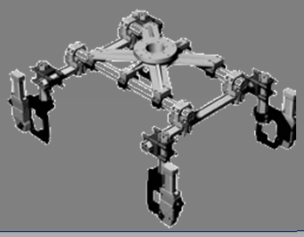
- The tool attached to the robot arm that actually performs the work.
  - Vacuum Cups
  - Grippers
  - Spatulas / Fingers
  - Spray Nozzles
  - Dispensers
  - Buffing Wheels
  - Machine Tools
  - Water Jets
  - Welding Torches
  - Resistance Welding Guns
  - Saws
  - Laser Cutters
  - Ladles

Adds to the Work Envelope
Adds to the Payload / Torque / Inertia

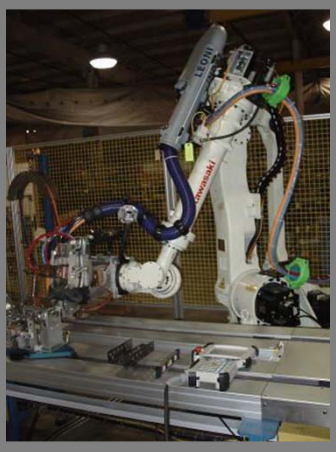



End of Arm Tooling Considerations

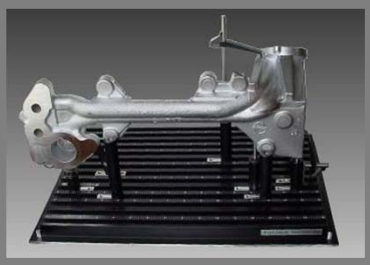
- Tooling Vendors
  - Purchased Component
- Design Considerations
  - "Building Blocks"
  - Repeatable and Positive
  - Include Sensors
    - Part locators / verification of action / QC
  - Environmental Considerations
- Tool Changers
  - Manual
  - Quick change
  - Automatic

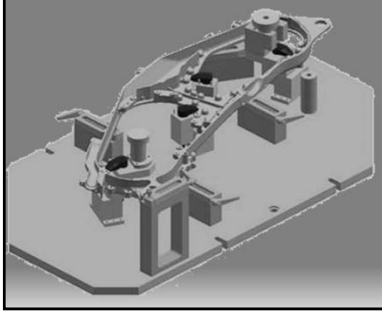


Arm Dressing / Cable Management



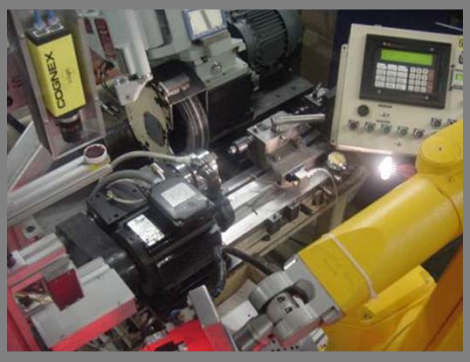
Part Fixture Considerations





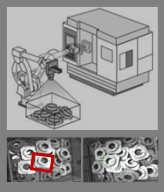
- Tooling Vendors
  - Purchased Components
- Design Considerations
  - Repeatable and Positive
  - Sensors
    - Part locators / verification of action / QC
  - Environmental Considerations
- No Parts Fixture?
  - Can Locate – sensors or vision
  - Fixture less system design
  - Cooperative motion

Vision Systems

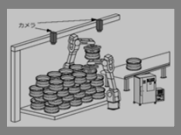


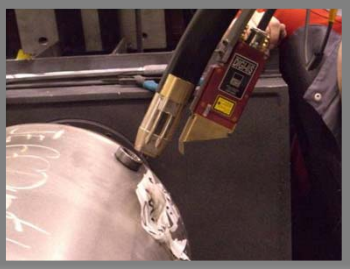
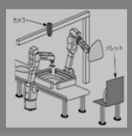
- Peripheral Equipment
  - Camera
  - Camera Controller
  - Light Source
  - Calibration Check Means
- Robot Components
  - Robot and Controller
  - Interface to Camera Controller
  - Software
- Applications
  - Part Location
  - Robot Guidance
  - Inspection
  - Real Time Feedback

Vision System Applications







Robot Cell Safety

- **Responsibility**
  - **Robot Manufacturer**
  - **Integrator / System Builder / Installer**
  - **User**
- **Refer to Resources**
  - **ANSI / RIA R15.06-12**
  - **OSHA Standards**
  - **CUL / UL [Underwriters Laboratories]**
  - **Hazardous materials requirements**
  - **Local Codes**
  - **Good manufacturing practices**
  - **Plant Standards**
  - **Personnel training policies**

ROBOTIC INDUSTRIES ASSOCIATION

Robotic Industries Association
PO Box 3724
900 Victors Way
Ann Arbor, MI 48106
(734) 994-6088
www.robotics.org

System Safety Responsibilities

- Robot Manufacturer
  - All E-stops are hard wired
  - Mushroom Button E-Stops
  - Enabling device
  - Robot velocities are constantly monitored
  - Teach and Check velocities are reduced
  - Joints equipped with Hard Stops or Safety-Rated Soft Axis Limiting Devices
  - Joints equipped with Hard Stops
  - Joints equipped with over-travel limit switches
  - All robot axes have software limits for work space
  - Velocity and deviation errors are constantly monitored
  - All axes equipped with electromechanical brakes
  - Crash software
  - Error messages
  - Training
- System Integrator
  - Personnel barrier
  - Interlocked safety gates / light curtains
  - E-Stop switches strategically placed
  - Awareness barrier
  - Status beacon or signal
  - Maximum envelope marking
  - Behavior management
  - Training
  - Risk Analysis
- End User
  - Behavior Management
    - Personnel training
    - No tolerance on misbehavior
  - Maintain safety equipment
  - Risk Analysis

Resources in Robot Safety

- National Robot Safety Conference
  - Held annually in the fall in a Central U.S. location
- In House Safety Training
- Robotics Online e-Newsletter
- Workshops, Forum, Webinars and Conferences
- Integrator Certification Program
- RIA Resources and Books
- Ask the experts

Basic System Process Control

- Process Control
  - Communication to external equipment and production system
  - Operator Control of entire system
    - Philosophy with robot controller
  - Define where event is to occur in robot path – at end of move?
  - What action is to occur when the event happens
  - Program / Product Selection
  - Auto Start of entire line
- Process Monitoring
  - Data Collection
  - Diagnostics
  - Maintenance
  - Quality Control
  - Process Flow

System Control Philosophy

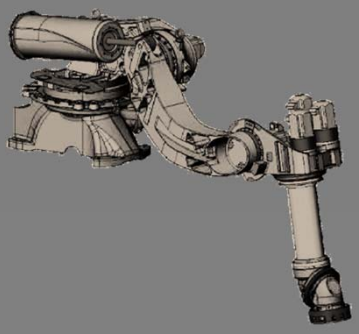
- Philosophy 1
  - Robot Controller does all
    - System I/O, Tooling Control, Motion Control, Operator Interface
- Philosophy 2
  - Robot Controller
    - Tooling Control, Motion Control
  - PLC or PC
    - System I/O, Operator Interface
- Philosophy 3
  - Robot Controller
    - Motion Control only
  - PLC or PC
    - System I/O, Tooling Control, Operator Interface
- Philosophy 4
  - Robot Controller
    - Robot Drives only (dumb motion controller)
  - PLC or PC
    - System I/O, Tooling Control, Operator Interface
    - System Controller has kinematics for the arm

Crashes

- *Crash Avoidance*
  - *Software Limits*
  - *Hard stops*
  - *Programming*
  - *Speed reduction in teach and check*
  - *Priority in Multiple robot cells*
  - *Master / Slave*
- *Crash Detection*
  - *Feedback*
  - *Mechanical Means*
  - *Crash Detection Software*

10+ Mistakes in Robot System Integration

- **Underestimating Payload, Torque and Inertia.**
- **Expecting the robot to do to much.**
- **Overlooking the need for options or peripheral equipment**
- **Underestimating Cable Management Issues.**
- **Not considering all current and future application needs**
- **Misunderstanding accuracy and repeatability.**
- **Not fully utilizing the capabilities of a robot**
- **Choosing a robot or system solution solely on price**
- **Failure to consider using robotic technology.**
- **Thinking that robots are to complicated.**
- **Focusing on the robot alone.**
- **Not planning for disaster.**
- **Not selecting the “easy” application first**



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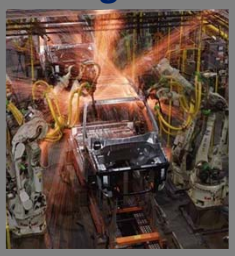
System Applications

- Spot Welding
- Arc Welding
- Coating & Dispensing
  - Less than 10 pounds
  - Greater than 10 pounds
- Assembly
  - Less than 10 pounds
  - Greater than 10 pounds
- Material Handling
  - Packaging / Palletizing
  - Machine Tending
  - Body Shop
  - Other Material Handling
- Material Removal
- Inspection

Spot / Resistance Welding

- **Product**
  - **Body in White**
- **Very Common Application in Automotive**
- **Motivation**
  - **Bulky and heavy Welding Gun**
  - **Significant Labor Savings**
  - **Consistency in weld process**
  - **Numerous welds per station**
  - **Shortens production line**
  - **Easier line changeover**



Automotive Paint

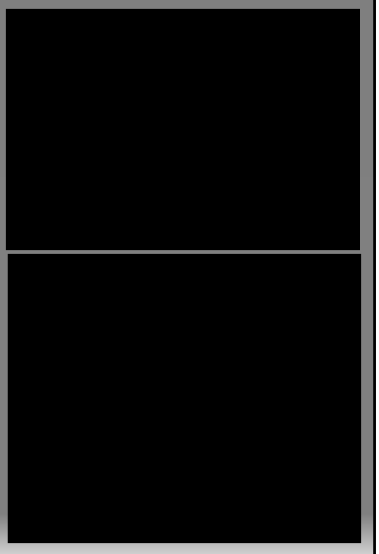
- **Product**
  - **Automobile Body**
- **Motivation**
  - **Fully automated system**
  - **Automated color change based on production menu**
  - **Person is not in the breathing apparatus**
  - **Person is not in Explosion Proof area**
  - **Finish Quality**
  - **Production Speed Needs**

Coating and Dispensing

- **Products**
  - ATV Wheels
  - Oven Enameling
- **Motivation**
  - Person is not in the breathing apparatus
  - Person is not in Explosion Proof area
  - Finish Quality
  - Production Speed Needs

Assembly

- **Product**
  - Wiring Fluorescent Light Fixtures
  - Bending Orthodontic Braces
- **Very Tedious Process done manually**
- **Motivation**
  - Eliminated difficult manual process
  - Improve quality of wiring
  - Reduce wire use
  - Reduced pre-wiring operations
  - Standardized assembly



Material Handling

Shoe Polish Packages, Solar Cells, Raw Chickens, Vials

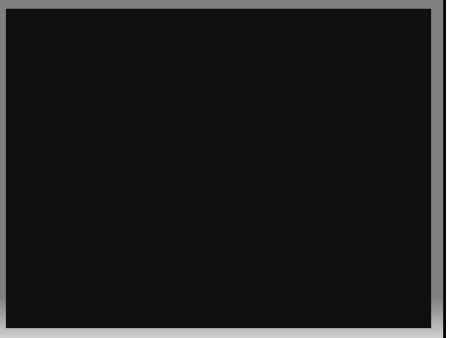
start on safe position

Material Handling - Palletizing

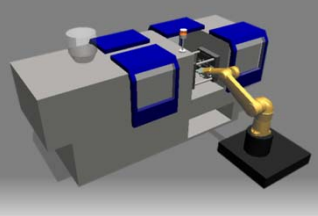
- Product
  - Bags
- Motivation
  - Eliminates Back Strain from Lifting
  - Eliminates Repetitive motion
  - Labor Savings
  - Requires numerous people per line
  - Difficult to get people to do this task
  - Quality of stack
  - Cost reduction

Material Handling - Packaging

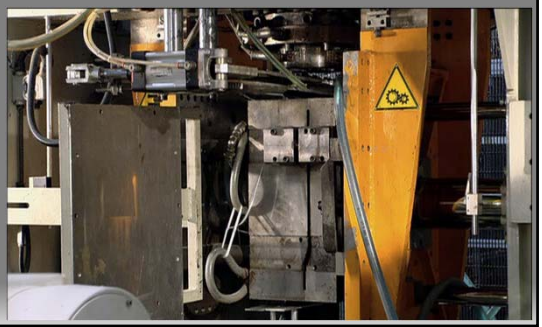
- **Product**
  - Cookies
  - Frozen Egg Rolls
- **Motivation**
  - Speed Requires many people
  - Repetitive motion causes injuries
  - Labor Savings
  - Difficult to get people to do this task
  - Quality of Package
  - Cost reduction



Machine Tending



- **Product**
  - Injection Molded Plastic Head Rest Parts
  - Forged Bearing Housings
- **Motivation**
  - Combines Operations
  - Eliminates Repetitive motion
  - Labor Savings
  - Difficult to get people to do this task
  - Cost reduction



Pork Ham de-boning

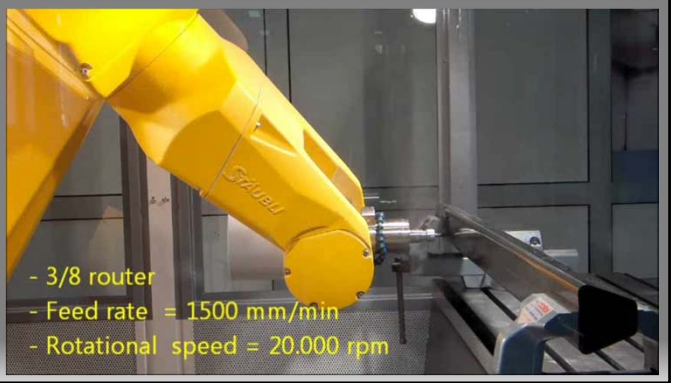
- Product
  - Hams
- Motivation
  - Eliminates risk of contamination
  - Removes people from wet area
  - Eliminates possibility of cuts
  - Increases yield (> 95%)
  - Huge cost savings

Material Removal - Water Jet

- Product
  - Cutting Jet Ski Bodies
  - Deburring Castings
- Motivation
  - Person not exposed
  - Labor Savings
  - Quality Improvement
  - Cleaner holes
  - Cost reduction
  - Consistency
  - Standardization of parts
  - Combined Operations and reduced cycle time

Machining

- **Product**
  - **Drone Frames**
- **Motivation**
  - **Quality Improvement**
  - **Response to changes / customization**
  - **Consistency**
  - **Highly accurate**



Material Removal - Grinding

- **Product**
  - **Gears**
- **Motivation**
  - **Highly Accurate**
  - **Repeatable Process**
  - **Consistency**
  - **Highly accurate**

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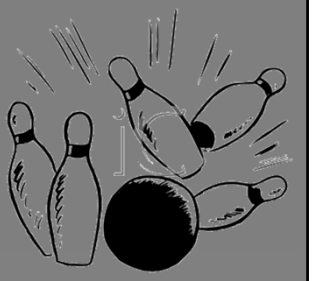
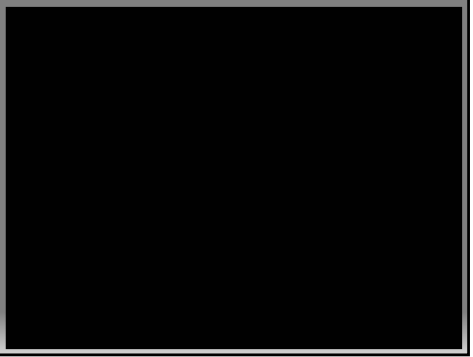
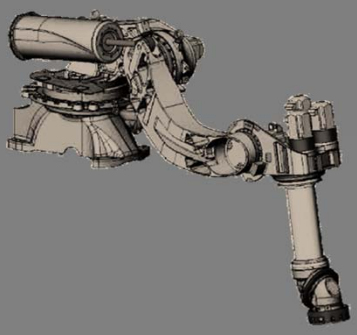
Robotic Bowling



- **Product**
  - **Bowling against a Robot**
- **Motivation**
  - **No Ergonomic Issues solved**
  - **No Labor Savings gained**
  - **Wins every game**



CONTACT INFORMATION



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