Robotics for Assembly Automation Tutorial

Robotic Industries Association
Presentation Overview

- Highlight Robots for Assembly Features & Benefits
- Explore “When & Why” To Incorporate Robotics for Assembly Automation
- Dispel Misconceptions about Robotics for Assembly
- Getting Started: How to Develop an RFQ
- List of Vendors and Additional Resources
Robotic Assembly Opportunity

• Properly integrated, today’s reliable robots offer tremendous opportunities for meeting the challenges of today’s dynamic products, product presentations and assembly lines.

• In addition, companies are commanding stringent operational conditions for 24/7 operations while still necessitating high reliability, low maintenance, flexibility and quick changeover between products.

• Today, robots are commodity products yielding superior performance, reliability and versatility.
Robotic Assembly Opportunity

- Robotics are being successfully implemented for assembly automation in numerous markets and applications including:
  - Aerospace
  - Agriculture
  - Appliances & Consumer Goods
  - Automotive
  - Building Products
  - Electronics
  - Energy Devices
  - Marine
  - Medical
  - Semiconductor
Robotic Assembly Opportunity

- Robotics provides a unique opportunity for assembly automation solutions. These opportunities include:
  - Minimize Risk
  - Minimize Product Handling
  - Minimize Damage To Product
  - Minimize Failure Opportunities
  - Minimize Operator Intervention
  - Minimal Product Change Over
  - Minimize Maintenance
  - Optimize Operational Performance
Robotic Assembly: Features & Benefits

- Understanding the features and benefits of using robots for assembly automation is best described when compared to “traditional” assembly automation technology.

- Key benefits of robotics over traditional include:
  - Higher Reliability
  - Robots Reduce Risks
  - Greater Flexibility & Versatility
  - Optimum Part/Product Handling
  - Quicker Changeover
  - Lower Maintenance
  - Greater Layout Flexibility
  - Control & Software
  - Common Technology Solution
  - Ease for Upgrade or Redeployment
  - Environment Compatibility
  - What is the real “system” cost?
Higher Reliability

• Robots (including controller) are proven to provide:
  – 50,000 to 100,000+ hours MTBF [Mean Time Between Failure] of operation without failure.
  • Equivalent to 25-40 “man-years”
Higher Reliability

• Robotic vs. Pneumatics
  – Robotic Pick & Place
    • Significantly simplified configuration
    • Substantial reduction in failure opportunities
Higher Reliability

• Robotic Components Required
  – Robot (4-6 axes) [50,000+ MTBF]
    • Includes controller
    • Includes collision guard software eliminating break-away device
  – Gripper

• Pneumatic Components Required (per one axis only)
  – Axis slide
  – Axis sensors/brackets/cables/connectors (2 each)
  – Hard Stop (2)
  – Shocks (2)
  – Mounting interface plates and hardware
  – Flow controls (2)
  – Valve/cable/connector
  – Pressure Regulator
  – Tubing and Connectors
  – Gripper
Higher Reliability

- **2-Axis Pneumatic Manipulator with one Rotary Axis**

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<th>Sensor</th>
<th>Cable</th>
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- **6 - Axis Robot**
  - *A robot can be considered as one component since it exceeds 50,000 MTBF*

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Higher Reliability

• Three-Axis Pneumatic Manipulator is *6-times More* likely to have a *Failure* than a 6-axis Robots

![Failure Opportunity Analysis](chart.png)
Higher Reliability

• Simplify part handling to minimize total number of system electrical/mechanical components.
  – For example, using vision and robot to locate and pick parts from a bin or off a moving conveyor eliminates collating, accumulating and orienting. It also reduces part jamming and part changeover seen with conventional feeding.

• Addition of automatic tool changer eliminates operator handling, storing and assembly of tooling

• Utilizing robot auxiliary axes for ancillary motion/control eliminates an additional servo/control/software platform.

• Utilizing 6-axis robots for part handling can eliminate complex pneumatic devices and changeover.
Robots Reduce Risks

- **Design Process Development**
  - Engineering costs are a fraction of traditional systems
  - Robot is one “Part”

- **Fabrication & Assembly**
  - Less electrical and mechanical components

- **Integration**
  - Reduced time for debug & fine tuning

- **Maintenance**
  - Less maintenance….grease axes every 6 months and change the battery once a year

- **Technical Risks**
  - Use of robots greatly reduces risk from variations or changes during project

- **Greater Flexibility**
  - During and after project completion

- **Reduced Schedule**
  - Robots greatly reduce assembly and debug time

- **Reliability**
  - Not only are robots more reliable than traditional systems, they typically eliminate the total number of components in a system by performing multiple tasks
Greater Flexibility & Versatility

• Robotics can be configured to optimize the part/product handling compared to traditional assembly machinery which has a fixed footprint, component in-feed and assembly out-feed.

• Robotics provides the ability to easily design around the process/application instead of forcing a “standard “designed machine or limited function devices onto the process.
Greater Flexibility & Versatility

• **Examples of Robot Flexibility & Versatility**
  – Vision and Sensor Guidance
    • Vision/sensor guided part feeding verses fixed hard automated parts feeders
  – Picking of parts from multiple locations and heights
  – Mixtures of parts/products can be created by bringing in multiple in-feeds.
  – Picking of multiple part types with the same robot
  – 6-degree freedom robots enable optimum motion for assembling parts
  – Optimizing speed/motion while minimizing part handling. A robot can pick and place gently while moving from point to point high-speed with controlled acceleration & deceleration
Optimize Part/Product Handling

• **Speed**
  – Optimizing speed/motion while minimizing part handling. A robot can pick and place gently while moving from point to point very fast and with controlled acceleration/deceleration.

• **Assembly**
  – 6-degree freedom robots provide optimum motion for assembling parts. For example, a circuit board can be “rocked” at an angle into a mating part instead of straight in which requires almost a perfect alignment of both parts.

• **Quality**
  – Replacing the “bang-bang” motion of pneumatics with optimized motion profiling of a robot increases product quality.
Quicker Changeover

- Product changeover can be minimized or even eliminated with the use of “Tool Changers”.
- Automatic tool changers are available for all ranges of robots and payloads.
Quicker Changeover

- Incorporating the dexterity of a 6-axis robot reduces the number of electrical/mechanical devices required with conventional configurations.
- Database programming allows computing of robot motion based on product parameters which reduces the amount of robot programming when changing process or parts or product types.
Lower Maintenance

• When using the robot to simplify the system design and operation, the total number of electrical and mechanical components to maintain/repair in the system can be significantly reduced.
• Robots are virtually maintenance free typically requiring only greasing every 6 months to 3 years and changing of batteries annually.
• Tool Changers increase reliability by eliminating operator intervention of the tool, system and changeover procedure.
Greater Layout Flexibility

- Robots provide for design freedom to configure a system to optimize space and operations.

  - Traditional Automation
    - More Cost
    - More Footprint
    - \( \approx 90\% \) More Maintenance
    - \( \approx 10x \) More Failure Opportunities

  - Robotic Automation
    - Less Cost
    - Less Footprint
    - \( \approx 90\% \) Less Maintenance
    - \( \approx 10x \) Less Failure Opportunities
Robots Provide Accurate Simulations

- Use of robots allows highly accurate simulations to greatly reduce risk and product development.
Control & Software

- Robot controllers are highly advanced taking advantage of the latest in safety, communication, HMI, web interface, simulation, on-line documentation, integrated vision/intelligent sensors and application specific software.
- Robot controllers can be used to control the entire assembly solution including I/O, HMI’s and additional servo devices such as collators and metering conveyors.
- Ethernet communication provides reliable control interface to I/O and other equipment.
- Database driven software reduces or eliminates changeover.
- “Collision” Guard Software Protects Robot, Tooling and Product.
- “Soft Float” Software allows X-Y “Float” during part placement.
- 6-axis “force sensors” provide “intelligent” assembly.
- Remote connectivity provides remote support capability.
Common Technology Solution

- Allows common platform for multiple assembly stations
  - Same brand robots typically utilize common control platform
- Common platform across multiple factory applications
  - For example the same robot brand can be used for raw material handling, machine load/unload of components, assembly, testing, packaging and palletizing
Ease for Upgrade or Redeployment

• Upgrading for new products/processes is minimized.
  – Typically, changes are limited to robot tooling and programming.

• Robots can be redeployed for new applications if product/processes become obsolete or are moved to another facility.
Environmental Compatibility

- Robots are available and proven for most any application and environment.
  - Clean Room
  - Cold
  - Dusty
  - Explosive
  - Heavy
  - Hot
  - Noisy
  - Radiation
  - Sanitary
  - Wet
What is the real “system” cost?

• Costs to be considered are more than just “Materials”!
  – The true costs for the non-robot solution can be significant and include:
    • Engineering
    • Documentation
    • Fabrication
    • Assembly
    • Debug
    • Installation
    • Support
    • Changeover
    • Performance & Functionality
    • Risk, Rework….Redesign

Remember, the robot is “one” purchased component!
Robotic Assembly: When & Why?

• Use “Robotic Assembly” if your parts, assembly processes or product presents any of the challenges called out below:
  – Parts are difficult to feed, orient or accumulate
  – Variety of part or product types
  – Limited timeline for project development and integration
  – Short product life cycles
  – Traditional automation solutions would require a large number of pneumatic devices.
  – Product assembly has potential for process “simplification” if robots are used.

• Process
  – Variability in processes from one product to another
  – Ergonomic Issues
Robotic Assembly: When & Why?

- **Facility/Line Configuration**
  - Multiple Lines
  - Minimal Space
  - Minimal Accumulation due to space
  - Utilization of existing material handling or peripheral equipment

- **Operational Challenges**
  - High frequency of changeover
  - Difficulty to ramp up production between changeovers
  - Market driven changes in product and product presentations
Robotic Assembly: Misconceptions

• If you’re trying to improve your assembly process, don’t be misled by these old misconceptions about robot reliability, complexity and costs.
  – Robots cannot handle high speed lines
  – Robotics technology is complex
  – Robotics requires higher skilled operators and support personnel
  – Robotic solutions are unreliable
  – Robotic solutions are expensive

None of these statements are true!
Getting Started: Developing an RFQ

• Assembly automation analysis requires a detailed functional requirement analysis to develop an RFQ [Request for Quotation].

• It is critical that all parts/components, assemblies, processes, throughput rates, plant layouts and assembly details be included in the RFQ.
Getting Started: Developing an RFQ

- A RFQ (Request For Quotation) should include a Functional Requirements Specification (FRS)
  - Functional Requirements Specification
    - The purpose of an FRS is to define the projects requirements without providing any concept or solution.
    - *Must be complete before concept and proposal/quotation*
Getting Started: Developing an RFQ

• FRS should include the following:
  – Title Page
  – Revision & TBD
  – Scope
  – Associated Documents
  – Project Overview
  – System Functionality
  – Process Overview
  – System Configuration
  – Production Requirements
  – Reject/Failure Requirements
  – Critical Assumptions
  – Project Risks
  – Project Management Plan
  – Qualification Requirements
  – Sample Requirements
  – Additional Requirements
Developing an FRS

• When developing a FRS it is vital to clearly assess and understand the requirements including:
  – Product Description
    • General Description of product and assembly process
    • Detailed part and assembly drawings
    • Pictures & Samples
  – Assembly Process
    • Thorough machine cycle rate analysis [see later slides]
    • Detailed process documentation such as welding or bonding specifications/requirements.
  – Testing & Qualification
    • Detail test plan for BOTH process steps and final product qualification.
Developing an RFQ: Project Requirements

- Other product, process or general requirements or issues
  - Assembly Constraints
  - Quality and Reliability
  - Product mix-up validation
  - Machine Noise Limits
  - Operator Height Range
  - Data Acquisition
  - Validation & Certification
  - Project Timeline
  - Expected uptime and efficiencies
Machine Cycle Rate Analysis

- **Determining Machine Cycle-Rate**
  - Assembly system cycle-rate has a significant impact on the concept, design and project success.

- **A Perfect World** – 100% Efficiency – Does NOT exist!
  - Example shows a machine cycle rate of 5.18 seconds

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<td>Annual Production (# of Parts)</td>
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\[
\text{Annual Gross Hours} = \text{Shifts} \times \text{Days} \times \text{Hours} \times \text{Weeks} \\
3,600 \times 3 \times 5 \times 5 \times 48
\]

\[
\text{Annual Available Hours (Net)} = \text{Annual Hours} \times \text{Availability} \times \text{Efficiency} \times \text{Yield} \\
3,600 \times 100% \times 100% \times 100%
\]

\[
\frac{\text{Seconds Per Part}}{\text{Parts Per Hour}} = \frac{\text{Available Sec.}}{\text{Annual Units}} \\
\frac{5.18}{12,960,000} = \frac{2,500,000}{694}
\]
Machine Cycle Rate Analysis

• **Conservative Analysis**
  – Example shows a machine cycle rate of 4.14 seconds
    • 85% Machine Availability [parts available shift changes, etc…]
    • 95% System Efficiency
    • 99% Product Yield [1% scrap]
Machine Cycle Rate Analysis

- **Realistic Analysis**
  - Example shows a machine cycle rate of 4.63 seconds
  - 92% Machine Availability [parts available shift changes, etc…]
  - 98% System Efficiency
  - 99% Product Yield [1% scrap]

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- **Annual Gross Hours**
  - \(3,600 = \text{Shifts} \times \text{Days} \times \text{Hours} \times \text{Weeks}\)
  - Annual Hours (Net) = Annual Hours \times Availability \times Efficiency \times Yield
  - Annual Available Seconds (Net) = 11,567,889
  - Seconds Per Part = Available Sec. \div Annual Units
  - Parts Per Hour = 778
Project Management

• **Functional Requirements Specification**
  – Complete prior to Contract Award

• **Preliminary Design Review**
  – Complete Preliminary Design Specification
  – Block Diagrams Complete
  – Software Requirements Defined
  – Ordering of Long-Lead Components [i.e. Robot]

• **Final Design Review**
  – Complete Final Design Specification
  – Final Layouts
  – List of all Major Components
  – Detailed I/O Lists
  – Operation Specifications Complete
  – Software Flow Complete

• **Preliminary Acceptance**
• **Qualification of System**
  – Installation & Training
  – Final Acceptance
  – Qualification of System

• **After Sales Support**
Robot “Peripherals” for Assembly

• Incorporating other robot peripherals will optimize the robot(s) capability while significantly increasing system reliability and flexibility.
  – System Chassis Configuration
  – Machine Vision & Sensing
  – Part Handling Components
  – Assembly Test & Qualification
  – Software & Control
Peripherals: Chassis Configurations

- The “chassis” configuration provides the means for indexing the “assembly” through the assembly automation process.
- Robots provide the flexibility to easily integrate into any configuration.
- Chassis configurations may include:
  - In-line, Rotary Dial, Work Cell, Carrier Strip, Blow Feed, Hybrid… and more
Peripherals: Chassis Configurations

• **In-Line**
  – Power & Free
    • Using pucks/pallets which float/travel on continuously running “belt”.
  – Precision Indexing
    • Carousel or Over-Under
  – Walking Beam
Peripherals: Chassis Configurations

• **Rotary Dial**
  – Assembly rides in fixtures which are indexed from station to station on a rotary dial.

• **Work Cell**
  – Robots or operators provide “indexing” of assembly
Peripherals: Chassis Configurations

• Carrier Strip
  – Example of a creative solution whereby the assembly is performed with the “body” of the assembly still attached to a carrier strip.
  – The strip is indexed using the excise die.

• Blow Feed
  – Transfer of assembly by “blowing” part from one station to another.
Peripherals: Chassis Configurations

- Hybrid
Peripherals: Vision & Sensors

- Machine Vision/Sensors
  - Parts Handling
  - Part Identification
  - Robot Guidance
  - Assembly Verification
  - Package Verification
Peripherals: Vision & Sensors

• **Machine Vision Adds Flexibility**
  – Provides for Easy, Frequent Part Changeovers
    • Load New Projects As Needed From Robot Control
  – Adapts to Process and Part Variations
    • Parts Change in Overall Size
      – Measured Change Provided to Robot
    • Provides Data About Parts
      – Color, Size, Quantity …
  – Locates and Ids Multiple Parts
    • Identifies Which Parts Are Available
    • Provides Location for Each Part
  – Handle Random Orientation of Product
  – Reusable for Processing of Multiple Applications
  – Flexible Feeding using Robotics and Smart Feedback Systems
Peripherals: Vision & Sensors

• **Vision Reduces Cost**
  – Less Dedicated Tooling
    • Pick Parts Directly From Skid, Bin, Conveyor or Machine
  – **Reuse of Conveyance and Equipment**
    • Often Enables the Use of Existing Equipment
  – **Simplifies the Installation**
    • Less Components to Setup and Maintain Is Better
  – **Reduced Production Costs**
    • Less Inspectors
    • Fewer Machine Operators
    • Reduced Rework and Scrap
Peripherals: Vision & Sensors

- Robotics with Vision Increases Competitiveness
  - Enables New Applications
  - Adds Flexibility to the Robot
  - Lowers Costs
  - Improves Quality
  - Expandable for Changing Parts or Operations
  - Reduces Design and Build Effort
  - Provides Short Installation Times
Peripherals: Vision & Sensors

- Vision provides the ability to locate and orient part for assembly
Peripherals: Vision & Sensors

- Part identification and validation using vision
Peripherals: Vision & Sensors

- Vision for verifying assembly processes
Peripherals: Part Feeding

- **Products/Parts Feeding**
  - *Most system problems are due to PRODUCT QUALITY or “PRESENTATION” issues*
    - It is also where engineers tend to spend the least amount of effort during the design process.

- Many methods for presenting product to robot
  - Loose (bulk)
  - Accumulated (conveyor)
  - Random (conveyor)
  - Trays
  - Magazines
  - Taped Reels
  - Carrier Strip
Peripherals: Part Feeding

- Regardless of the “feeding” method, consider these general requirements:
  - Feed Rate (parts per minute)
  - Part Orientation [both in-feed and assembled/packaged]
  - Part Variability
  - Number of hours of part storage/buffer (usually 2 hours).
  - Load height (typically doesn’t exceed 65 inches)
  - Part Sensitivity to scratching or marring
  - Noise
Peripherals: Part Feeding

• Part Feeding
  – Bowl Feeding
  – Step Feeding
  – Flexible Feeding
  – Flex Bowl Feeding
  – Bin Picking
  – Tray Handling
  – Magazine Feeding
  – Tapes and Reel Feeding
  – Carrier Strip Feeding

Most can be simplified by….

…incorporating a robot/vision into the feeding scheme!
Peripherals: Part Feeding

• Bowl Feeding
  – Bulk load
  – Vibrate or Centrifugal
  – Orient and Lane Parts
  – Singulate for Transfer
Peripherals: Part Feeding

- **Step Feeding**
  - Bulk Load
  - Quiet
  - Gentle on Parts
  - Compact
  - Very Reliable
  - “Lower” Rates
Peripherals: Part Feeding

• Flex Bowl Feeding
  – Feed variety of parts in ONE bowl
  – Bowl feeding without final orientation
    • Feed parts only “right side” up
    • Utilize vision to locate part and robot to orient
Peripherals: Part Feeding

- **Flexible Feeding**
  - Incorporates vision to simplify the mechanics
  - Increases Flexibility
  - More tolerant to part variances
Peripherals: Part Feeding

- **Bin Feeding**
  - Layered or Bulk
  - Incorporates vision and/or sensors to locate for robot pickup
Peripherals: Part Feeding

- Tray Handling
- Magazine Feeding
- Tapes and Reel Feeding
- Carrier Strip Feeding
Peripherals: Test & Qualification

• Robots are often used for in process and final qualification of the assembly.
  – Assembly Tests
    • Leak
    • Torque
    • Sheer or Tensile
    • Force
    • Angular
    • Rotational
  – Functional Test
    • Full or Partial test of assembly as an operational “product”
Peripherals: Software & Control

• Historically, engineering for automation has emphasized mechanical design over software or control.

• Robot Controller, PLC or PC controls are normally used as the “main” controller. Larger lines have a Host-Line Controller.

• When choosing a control platform, be aware that the majority of software for a quality assembly system is for:
  – Error and emergency stop recovery, part tracking and operator interface. The actual assembly control is very rudimentary, as long as the control code is highly structured.
Control and Interface (HMI)

• At a minimum, software and the HMI Interface should include:
  – Graphical User Interface Touch Screen
  – Automatic, Manual, Audit and Re-Test Modes
  – Basic Process Tracking
  – Automatic Diagnostics for all feedback devices including sensors
  – Single Step/Cycle of each station process
  – Low Parts Indication
  – E-stop and Error recovery

• The challenge is to provide “simplistic” control architecture with “complex” or “sophisticated” control capabilities.
Case Study: Key Fob Assembly

- Robots (6)
- Vision Inspection (8)
- Vibratory feeders (8)
- PCB Tray handling
- Power-free conveyor system
- Distributed network control
- PC Network for vision and remote access
- Process tracking, remote access and automatic diagnostics
Case Studies: Key Fob Assembly

Upper Housing
- Verify 3 hole or 4 hole
- Date Stamp
- Robot with Flex Feeder places housing into pallet

Keypad
- Vision Verify (Object Recognition)
- Robotically place into Upper Housing

Transmitter PCB
- Robotic handling of trays and PCB
- Vision Inspect for battery seat & model number
- Robotically place into keypad

Lower Housing
- Vision OCR Part Number
- Robot with Flex Feeder places housing
- Pneumatic “snap” and sensor probe assembly verification

Key Ring
- Robot removes Fob from pallet and positions for assembly of ring
- “Ringer” assembled
- Robot presents assembly for “ringer” vision inspection
Case Study: Automotive Sensor

• Unique configuration integrated in phases to minimize risk and maximize overall project success.
• Common control platform for all sub-systems
• Phase-1: Final assembly of the automotive sensor product assembly.
• Phase-2: Assembly of the “float” sub-assembly
• Phase-3: Assembly of internal switch assembly.
• Phase-4: Product calibration, functional test and pack out.
Phase-1: Final Product Assembly

- Robots (3)
- Rotary Dial Indexing
- Bowl Feeders (3)
- Vision Guidance
- Rotary Indexing
- RTV Dispense
- Orbital Welding
- Leak Test
- Part Sorting
- Data Acquisition
- Two Part Types
- 800 parts/hour
- 1 part/4.5 seconds
Phase-2: Float Sub-Assembly

- Bowl Feeders (1)
- Vision Inspection
- Assembly
- Insertion Testing
- Blow Feeding
- Part Sorting
- Data Acquisition
- Two Part Types
Phase-3: Internal Switch Assembly

- Robots (1)
- Carrier Strip Indexing
- Vision Guidance
- Vision Inspection
- Precision Indexing
- Resistive Welding
- Crimping
- Part Sorting
- Data Acquisition
- Two Part Types
Phase 4: Calibration, Test & Pack Out

- Robots (2)
- Vision Inspection
- Rotary Indexing, Precision Indexing and Power-Free
- Functional Test
- Part Marking
- Part Sorting
- Packaging
- Data Acquisition
- Two Part Types
- 800 parts/hour
- 1 part/4.5 seconds
Case Study: Automotive Sensor

• Assembly of three unique sensor configurations using six axis robots to accommodate the differing geometries and processes.
  – Robots (6)
  – Bowl Feeders (5)
  – Pocketed Tape Feeder
  – Precision Indexing Axial Components
  – Component Form & Excise
  – Resistive Welding
  – Leak Test, Functional Test
  – Vision Inspection
  – Lubrication
  – Part Marking & Part Sorting
  – Data Acquisition
  – Two Part Types
  – 720 parts/hour
  – 1 part/5 seconds
Case Study: Medical Component

• Precision assembly of filament component based on real-time vision guidance.
  – Robots (2)
  – Shuttle Indexer
  – Laser Welding
  – Real-time vision feedback and Inspection
  – Database part configuration for 70+ part variations
  – PC Based Robot Controller and Interface
  – Statistical Process Control
  – Part Identification

• Large robot provided both manipulation of vision camera to locate part in relationship to mating housing geometry and laser welding of filament.
  – Automatic tool changing was incorporated to switch from manipulating camera and laser.

• Small robot provided manipulation of filament based on larger robots analysis.
Case Study: Gauge Assembly

• Automatic gauge assembly incorporating robots for part handling, tray handling product assembly.
  – Robots (4)
  – Rotary Dial
  – Bowl Feeders (5)
  – Robotic load/unload
  – Robotic tray handling
  – Robotic assembly
  – Torque drivers (2)
  – Taper