Kicking Ro-butt
The Challenges of a Robotic Safety Program

amazon robotics

We Reimagine Now

Agenda

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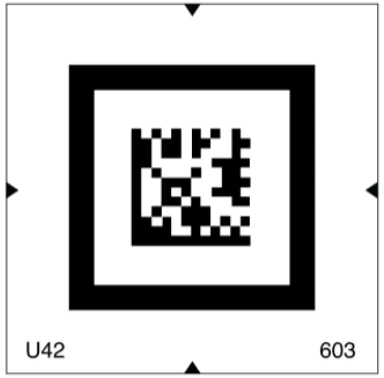
Where Have We Been…. A Little History

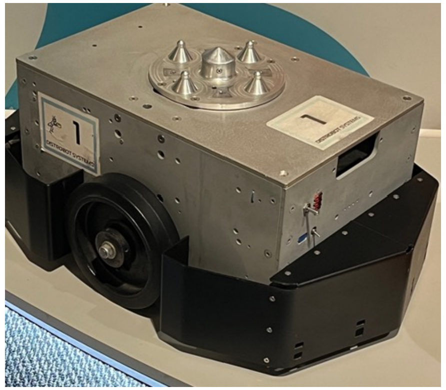


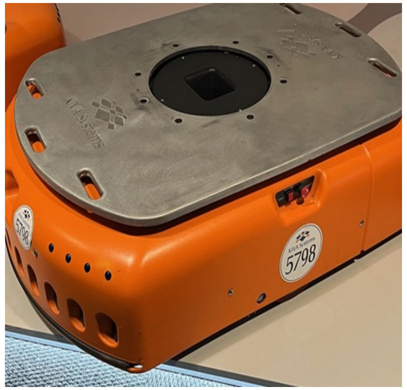
- Amazon Robotics, Formerly Known As Kiva Systems
  - Manufactures mobile robotic fulfillment systems
  - Automated storage and retrieval systems
  - Goal – eliminate the walking - bring the consumer commodity to the associate
- First Foray Into Robotics – Drive Units
  - Consumer goods stored in portable storage units called “pods”
  - When an order is entered into database system, software locates closest automated guided drive unit to a pod that contains the item and directs it to retrieve it
  - Mobile robots navigate warehouse floor by following a series of computerized bar code floor stickers
  - When drive unit reaches targeted pod, it slides underneath the pod and lifts it off of ground
  - Drive unit robot carries pod to associate pick item from pod compartment

Where Are We Going……

- Amazon Robotics Present Day
  - 2 Manufacturing and R&D combination sites in Massachusetts
  - Numerous Lab and R&D spaces in US, Belgium, Italy, Germany, and Canada
  - Moving into robotic manipulation units
  - Have manufactured and deployed over 800,000 drive units in the field

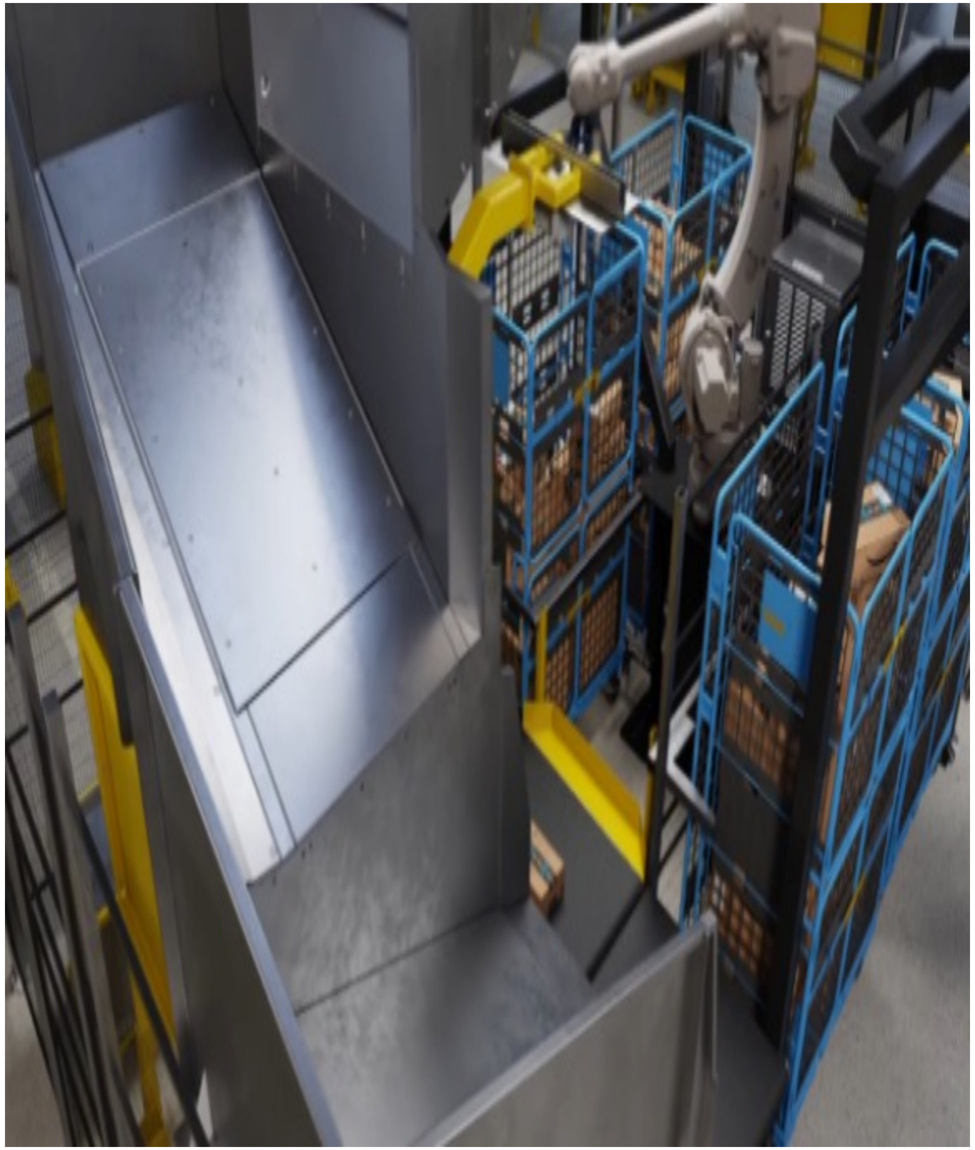
Enough about AR – lets talk about robotic safety…..





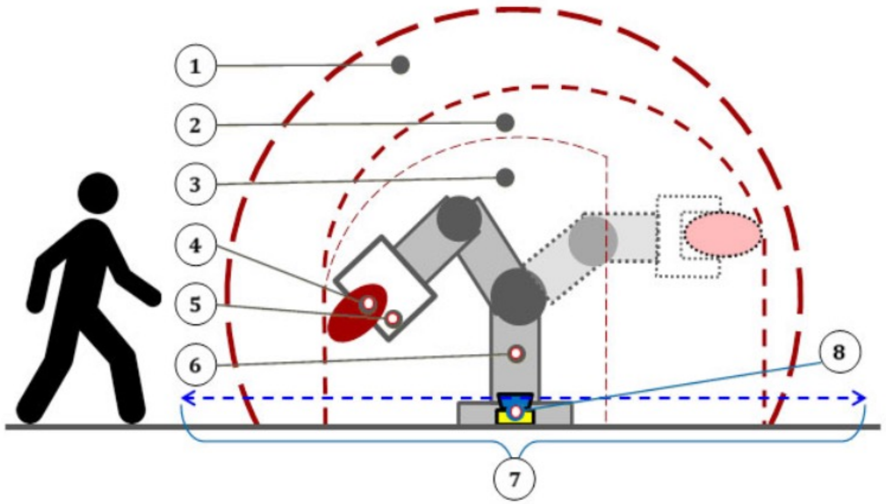
Definitions

- Robot
  - Automatically controlled
  - Reprogrammable multipurpose manipulator
  - Programmable in two or more axes
  - Can be used either fixed in place or mobile
  - Used in automation applications
- Robot System
  - System comprising of…..
    - Manipulator
    - Control system
    - Teach pendant
    - End effector(s)



Definitions

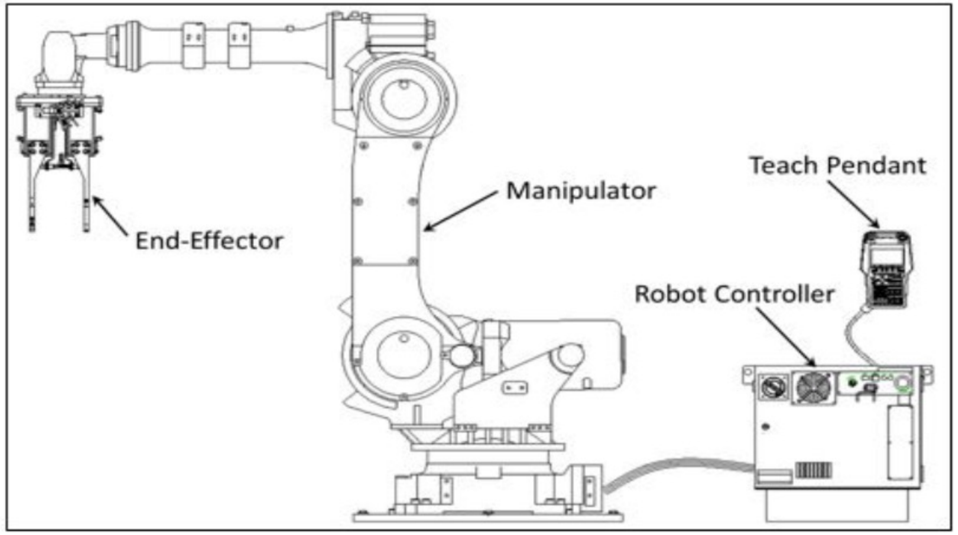
- Maximum Space
  - is the actual reach the robot is capable of, including the end or arm tooling
- Restricted Space
  - Portion of the maximum space restricted by limiting devices that establish limits that cannot be exceeded
- Operating Space
  - Portion of the restricted space that is actually used while performing all motions commanded by the task program
- Safeguarded Space
  - Space defined by the perimeter safeguarding



Key:		
	1 maximum space	5 end-effector
	2 restricted space	6 manipulator
	3 operating space	7 safeguarded space
	4 workpiece	8 protective device or barrier

Source: Robotics Industries Association (RIA)

Basic Components of A Robotics System



- Comprised of Four Major Components
  - Manipulator
  - Control System or Robot Controller
    - Interfaces for communication and input/output
    - Power supplied to the controller
  - Teach Pendant – program the robot
  - End Effector - engagement device that robot uses to lift item including;
    - Gripper
    - Vacuum
    - Pickers
    - Clamshell
- System is typically integrated with additional equipment including conveyors, worktables, elevators, process equipment (i.e. cutting, assembly, inspection), carts etc. to comprise a robotic application

Manipulators

- Physical Structure of the Robot
  - Structural frame
  - Supporting mechanical linkage, joints, guides actuators, sensors, & control valves
- Robot Model and Application
  - Dictate physical dimensions, reach, & weight carrying ability
  - Application requirements determine the needed specifications
  - Specifications can introduce hazards to associates integrating and operating robot

Control System

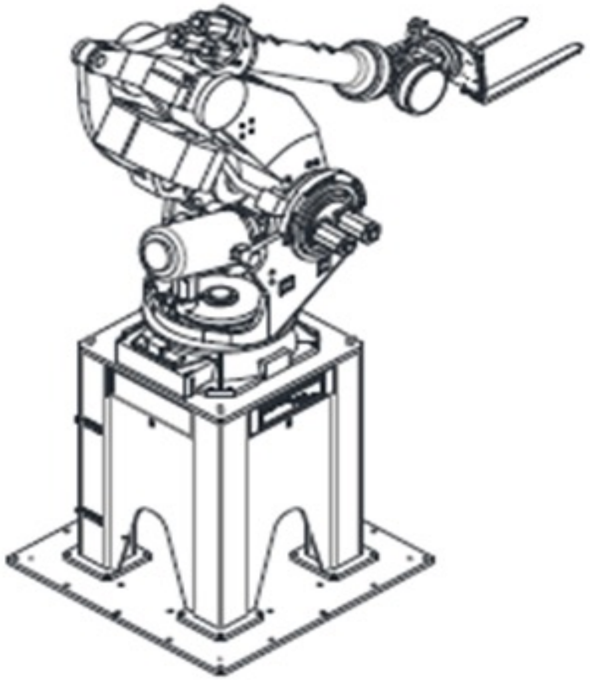
- Consist of Several Parts, Including:
  - Power Source
    - Energy is provided to various robot sensors, actuators, and their controllers in the form of electrical, pneumatic, or hydraulic power
    - Hazardous energy can exist in internal components such as capacitors, springs, pressurized cylinders, and other energy sources
  - Sensors
    - Used in robot systems to sense the location of mechanical portions of the manipulator and/or the end-effector, as well as to sense the location of objects exterior to the robot.
      - *Contact sensors*, which require physical contact against an object.
      - *Light sensors*, which detect changes in light.
      - *Distance sensors*, which can measure the distance the sensor is away from an object
      - *Motion sensors* which detect the motion of the robot or object
  - Input/Output signals
    - Computer or embedded microprocessors control robot systems
    - Perform computational functions and interface with and control associated sensors, end effectors and other peripheral equipment

Teach Pendant & End Effectors

- Pendants
  - Set Up of Robot Systems Utilizes Teach Pendant While in Manual Mode
    - Associate teaches robot its task(s) manually
    - Associate is in the “drivers seat” and is in control of the robot and the associated system equipment
    - Associate doing the teaching can be within restricted space of a robot cell, consequently mistakes in programming can result in injuries
- End Effectors – aka End of Arm Tooling (EOAT)
  - Type is dictated by application
  - Common end effectors include:
    - Grippers
    - Pickers
    - Cutting
    - Cameras
    - Force-torque sensors
    - Vacuums

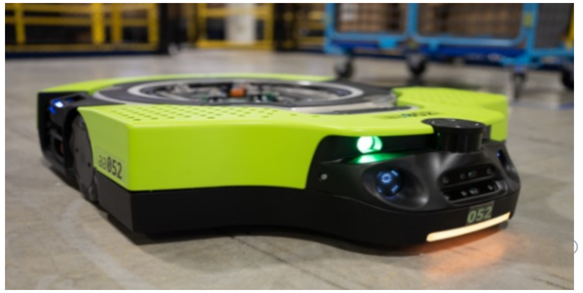
Industrial Robot Configurations

- Available in Wide Range of Sizes, Shapes, & Structures for Use in Different Applications
- Different numbers of axes available
- Influences Working Space Needed
- Common Types
  - Articulating
    - Have at least three rotary joints
      - number of joints on the robot determines its range of motion
      - can reach any point in their working space
  - Selective Compliance Articulated Robot Arm (SCARA)
    - Arms are flexible in the XY axis, but are rigid in the Z-axis.



Collaborative, Non-Collaborative, and Mobile Industrial Robots

- Robot Systems & Applications Are Further Divided Based On Degree of Interfacing Capability
  - Collaborative
    - Designed for direct interaction with workers
  - Non-collaborative
    - Designed without the need for direct interaction with workers
    - Separated from associates by means of traditional machine safeguarding
    - Designed to interact with other robots
  - Industrial Mobile Robots
    - Navigates autonomously within their operating environment to reach specified locations
    - Designed to automate transport tasks
    - Integrated with other technologies that identify obstacles that can hinder their trajectory
    - Uses obstacle avoidance to prevent possible impacts



Hazards Associated With Robot Applications

- Impact, Collision, or other "Struck-by/Caught-between" Hazards
  - Contact injuries caused by unpredicted or unexpected movements, component malfunctions, or unexpected program changes
- Crushing and Trapping Hazards
  - A body part can be trapped within or between a robot, end-effector, or workpiece and another robot, or other peripheral equipment
- Struck-by Projectiles Hazards
  - Breakdown of the end-effector, workpiece, peripheral equipment
- Electrical Hazards
  - system's power supply can present arc flash, shock, fire, and/or other electrical hazards
- Hydraulic Hazards
- Pneumatic Hazards

Robot Application Hazards by Process

Hazards of industrial robot applications can occur during any of the stages or processes associated with the typical lifecycle

- Manufacturing the Robot Systems and Applications
  - Impact, struck-by and caught between hazards or struck-by projectiles hazards likely
    - Assembly, installation, and testing are where workers are first exposed to the robot application.
    - These stages are when errors in design, assembly, and installation will occur
  - Electrical, hydraulic, or pneumatic hazards
    - Assembly and installation can also result in termination or connection errors that may not be discovered until the initial testing
- Integrating Robot Applications
  - total functionality of the robot application often cannot be fully completed until the robot system is integrated for use
    - This is often the first place where human interaction occurs in accordance with the robot's application. As a result, any of the hazards listed above are possible during the final assembly and integration process
- Operating and Maintaining Robot Applications
  - application programs are complex with some movements or actions happening infrequently, such that they might be unexpected

Sources of Robot Application Hazards

Common sources of hazards, of which some or all can be addressed by the proper design, testing, integration, operation, and maintenance of the robot and the robot application include:

- Human Errors of Integration and/or Programming
  - Incorrect activation of the teach pendant or control panel is a frequent worker error
  - Over familiarity with the application lends to complacency
  - Existing programming, interfacing peripheral equipment, or processing of live inputs-outputs by the robot controller can cause dangerous, unpredicted movement or action
  - Misunderstanding of the robot’s "direction of movement"
- Unauthorized Access
  - Entry into the restricted space because the worker involved is not familiar with the hazards, the safeguards in place, or their activation status

Sources of Robot Application Hazards, cont.

- Control Errors
  - Faults within the control system of the robot application, errors in software, electromagnetic interference, and/or radio frequency interference are control errors or faults
- Mechanical Failures
  - Inspection and maintenance activities should be performed in accordance with the manufacturer's requirements and in accordance with industrial standards to prevent mechanical part failure
- Time Pressure
- Environmental Sources
- Assembly & Installation Errors

Hierarchy of Controls – 3 Step Method

Move over Hierarchy of Controls Triangle…

Robotics Industries Use 3 Step Method…

Safeguarding requirements are placed primarily on the machine manufacturer and the robot application integrator, and finally on the employer/user

Designer Impact

Integrator Impact

User Impact

1	Inherently Safe Design Measures	Elimination
		Substitution
		Limit interaction
2	Safeguarding and Complementary Protective Measures	Safeguards & if applicable, Safety-Related Parts of the Control System (SRP/CS) *e.g. safety functions*
		Complementary Protective Measures • *Emergency stop devices and functions* • *Platforms and guard railing (fall prevention) & safe access – building codes & standards can apply* • *Measures for escape & rescue of people, isolation & energy dissipation, handling heavy parts*
3	Information for Use	Warnings & Awareness Means
		Administrative Controls
		Personal Protective Equipment

Source: Robotics Industries Association (RIA)

Safety From Concept to Operation

- Robot Manufacturers
  - Design, and implement robot applications that comply with:
    - Part-1 and Part-2 of ANSI/RIA) R15.06-2012, Industrial Robots and Robot Systems – Safety Consideration
    - requires that relevant, safe operating and maintenance information be provided with the robot (Part 1) and the robot system/application (Part 2)
- Robot Integrators
  - Part-2 of ANSI/RIA R15.06-2012
  - RIA Technical Report (TR) R15.606-2016, Robots and Robotic Devices – Safety Requirements for Collaborative Robots
    - requires that integrators must conduct comprehensive hazard analyses and risk assessments for each application
  - RIA TR R15.306-2016, Task-Based RA Methodology
- Robot System Operators and Employers
  - Part-2 of ANSI/RIA R15.06-2012
  - RIA TR R15.706, User Responsibilities
  - OSHA Requirements

Risk Assessment (RA)

Provision of ANSI/RIA R15.06-2012

- Each robot application should have an RA performed and documented prior to start up
- responsibility of integrator to ensure that an RA is completed and documented prior to start. It is also their responsibility to provide the results of the RA to the employer
- RAs must be completed for hazardous tasks within each stage of the robot application process (i.e. assembly, integration, operation, troubleshooting, and maintenance)
  - Foreseeable hazards and risks should be evaluated on materials being handled
  - Type of end effector being used and its operating speeds

Robot Safety Standards

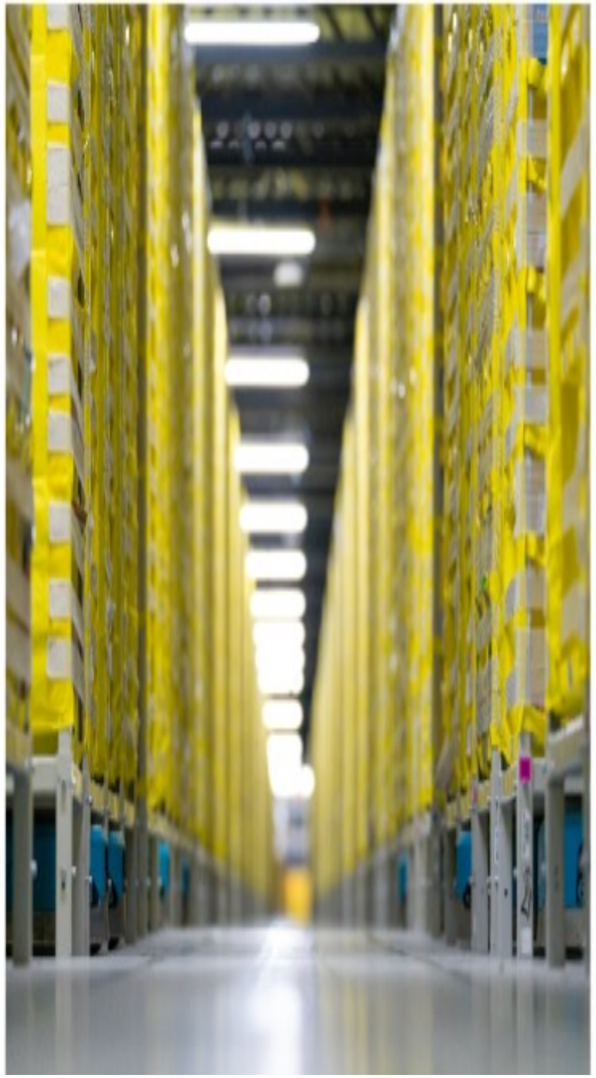
- Current National Standards
  - ANSI/RIA R15.06-2012
  - CSA Z434-14
- Current International Standard
  - ISO 10218-1:2011 Industrial Robots
  - ISO 10218-2:2011 Industrial Robots Systems & Integration
- Technical Reports
  - RIA TR R15.306-2016 – Task Based Risk Assessment
  - RIA TR R15.406-2014 – Safeguarding
  - RIA TR R15.606-2016 – Collaborative Robots (ISO/TS 15066)
- Other Robot Safety Standards
  - UL 1740

Summary

The number of robots present in workplaces is increasing, as are their capabilities. Robots enhance worker safety, health, and well-being by eliminating repetitive tasks such as lifting, moving, walking. Industrial robots are no longer confined to cages or cells. Today's robots are designed to work alongside and move amongst human workers.

Lessons Learned - Need to Up Our Safety Game

- Move beyond our dependency on OSHA regulations and embrace robotic safety guidance developed by trade and standard organizations such as ANSI and RIA
- It takes a village…. expand comfort zone of occupational safety to embrace and leverage other safety fields such as functional, compliance, deployment, etc.



Thank you.

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