

Industrial Robot Systems

A primer to robot identification and physical risks

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About the Risk Analysis Unit (RAU)

- A department in the Prevention Services division at WorkSafeBC
- Activities include:
 - Supporting prevention of workplace injury, illness, and disease by identifying and analyzing unaligned risks (not yet fully revealed by incidents and claims) and determining ways to mitigate those risks.
 - Providing risk reduction support to other WSBC departments such as risk advisories, inspection initiatives, education activities, and resource development.
 - Providing advice and support to regulatory bodies, including recommendations for regulation and guideline development.

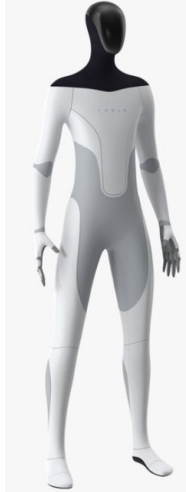
Contents

- 1 Industrial robots
- 2 Industrial robot envelopes (spaces)
- 3 Some hazards
- 4 Some hazard controls
- 5 Some key points

1. Industrial robots

Industrial robots

Tesla "Optimus" (Tesla Bot)



These are some examples of things
that might be considered robots...
but are they "industrial robots"?



Boston Dynamics "Spot"



Roomba Vacuum



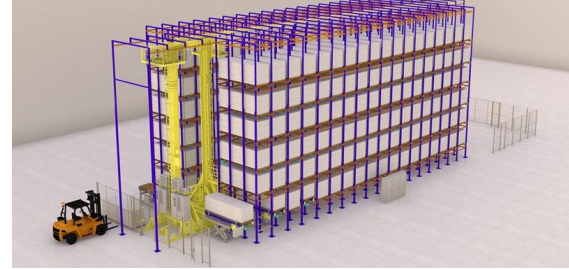
Drone



Service Robot



Automated Storage & Retrieval System



Automated Guided Vehicles



Autonomous Tractor



Industrial robots

These resources provide useful guidance on what “industrial robots” are?

Published WorkSafeBC guideline G12.83 identifies Z434-14 as an acceptable alternate standard to Z434-94



Harmonized

- **Canadian Standards Association**

- CAN/CSA-Z434-94 [referenced by OHSR s.12.83(a)]
- CAN/CSA-Z434-14 [adopts ISO 10218:2011]

- **American National Standards Institute**

- ANSI/RIA R15.06-1992 [referenced by OHSR s.12.83(b)]
- ANSI/RIA R15.06-2012 [adopts ISO 10218:2011]

- **International Organization for Standardization**

- ISO 10218:2011 [adopted by CSA & ANSI]
- ISO 15066 [collaborative robot supplement]
- ISO 8373:2021 [robotics vocabulary]

- **U.S. Occupational Safety & Health Administration**

- OSHA Technical Manual (OTM)
 - Provides information for OSHA Compliance Officers <https://www.osha.gov/otm>
 - Chapter 4 addresses industrial robots <https://www.osha.gov/otm/section-4-safety-hazards/chapter-4>

The CSA, ANSI, and ISO standards are harmonized



Industrial robots

CAN/CSA–Z434–94 and ANSI/RIA R15.06–1992

- **Industrial robot:** A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks.
- **Industrial robot system:** A system that includes industrial robots, the end-effectors, industrial equipment and the devices and sensors required for the robots to be taught or programmed, or for the robots to perform the intended automatic operations, as well as the communication interfaces required for interlocking, sequencing, or monitoring the robots.

CAN/CSA–Z434–14, ANSI/RIA R15.06–2012, and ISO 10218:2011

- **Industrial robot:** Automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be **either fixed in place or mobile** for use in industrial automation applications.
- **Industrial robot system:** System comprising industrial robot, the end-effector(s), any machinery equipment, devices, auxiliary axes or sensors supporting the robots performing its task.

Industrial robots

CSA-Z434-94, ANSI R15.06-1992

- State they **don't apply to** some things including but not limited to:
 - personal robots
 - automatic guided vehicle systems
 - undersea and space robots
 - automated storage and retrieval systems
 - automatic conveyor and shuttle systems
 - teleoperators (operated by remote control)
 - **mobile robots**
 - prosthetics and other aids for the handicapped
 - numerically controlled machine tools (CNC machines)

CSA-Z434-14, ANSI R15.06-2012, ISO 10218:2011

- add these items to the "don't apply to" list
 - micro robots (displacement less than 1 mm)
 - surgery or healthcare and service or consumer products
 - military robots
- remove these items from the "don't apply to list"
 - **manipulating portions of mobile robots**
 - **collaborating robots**

Based on definitions and scopes provided by CSA, ANSI, and ISO standards... "industrial robots" are...



Industrial robots



Articulated Robot



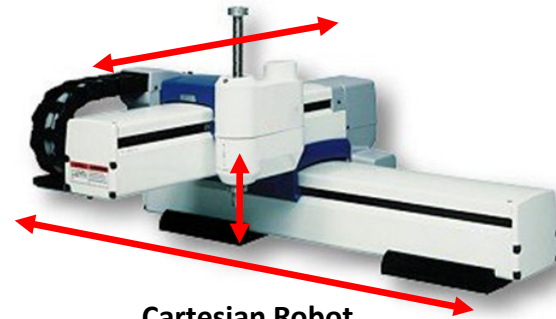
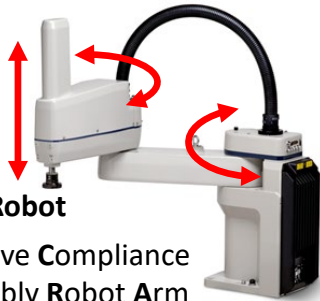
Industrial robots found in workplaces today are most likely one of these 4 types.

Delta Robot
(a.k.a. Parallel or Parallel Link)

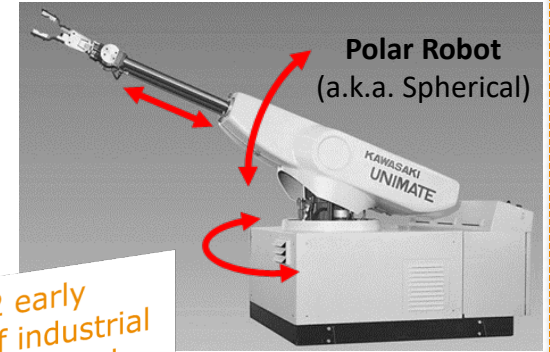


SCARA Robot

- Selective Compliance Assembly Robot Arm
- Selective Compliance Articulated Robot Arm



Cartesian Robot
(a.k.a. Rectangular, Linear, or Gantry)



Polar Robot
(a.k.a. Spherical)

These 2 early types of industrial robots are much less common in workplaces today.



Cylindrical Robot

Industrial robots

Collaborative Industrial Robots – “Cobots”

CSA-Z434-14, ANSI R15.06-2012, ISO 10218:2011

- Collaborative robot: A robot designed for direct interaction with a human within a defined collaborative workspace
- Collaborative workspace: A workspace within the safeguarded space where the robot and a human can perform tasks simultaneously during production operation
- Safeguarded space: Space defined by the perimeter safeguarding



The "cobot" in this picture is an articulated industrial robot.

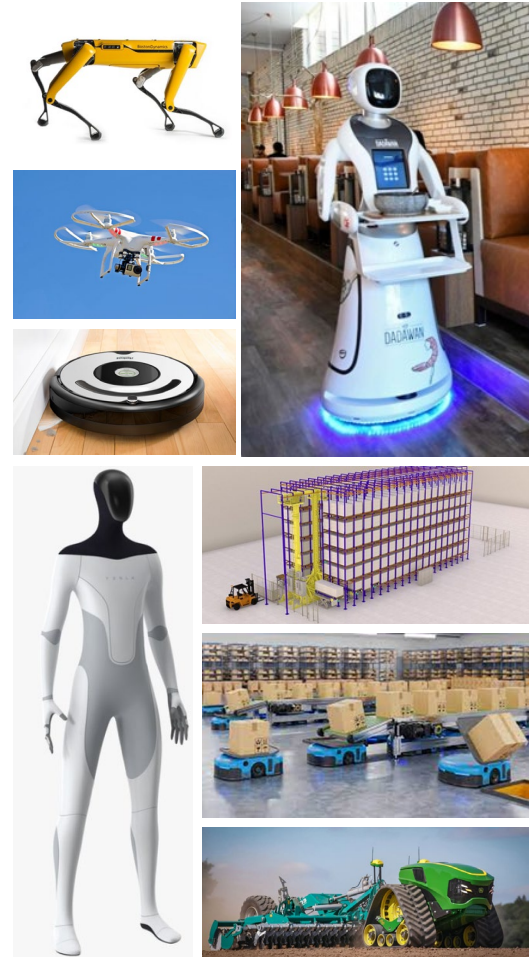
“Cobots” can safely operate simultaneously with humans in a collaborative workspace because their designs include one or more “additional safety functions”

1. Safety-rated Monitored Stop (SMS)
2. Hand-Guided Controls (HGC)
3. Speed and Separation Monitoring (SSM)
4. Power and Force Limited (PFL)

*Described later in
this presentation*

Industrial robots

- So... these are not “industrial robots”
- But... but they likely have hazards and pose risks
- If OHSR s.12.83 doesn't apply to them, what about... ?
 - 4.1 Safe workplace
 - 4.3 Safe machinery and equipment
 - 4.11 Startup
 - 4.33 Access to work areas
 - 10.3 When lockout required
 - 12.2 Safeguarding requirement
 - 19.36(10) Written safe work procedures including lockout procedures
- Perhaps others... including sections of the Workers Compensation Act... e.g., 21(1) & 21(2) regarding general duties



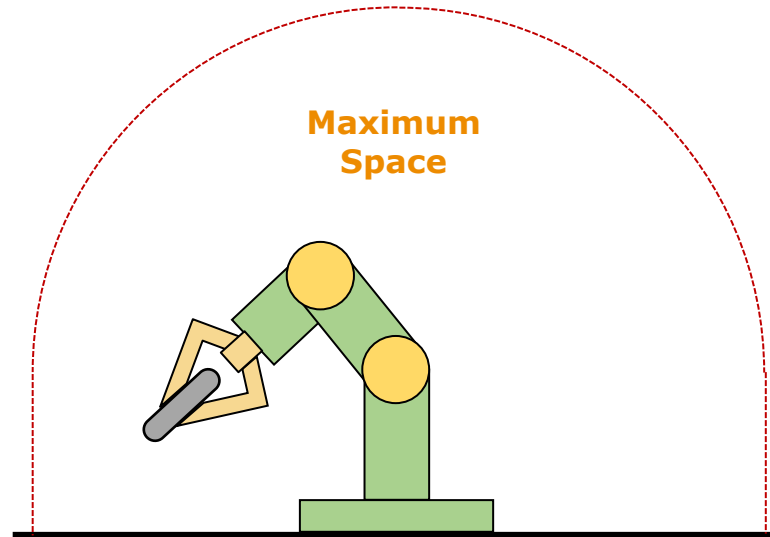
2. Industrial robot envelopes (spaces)

Industrial robot envelopes (spaces)

- **Every robot has three spaces**
 - Maximum space
 - Restricted space
 - Operating space

Industrial robot envelopes (spaces)

Maximum space – The space that encompasses the maximum designed movements of all robot parts including the end-effector, workpiece, and attachments.

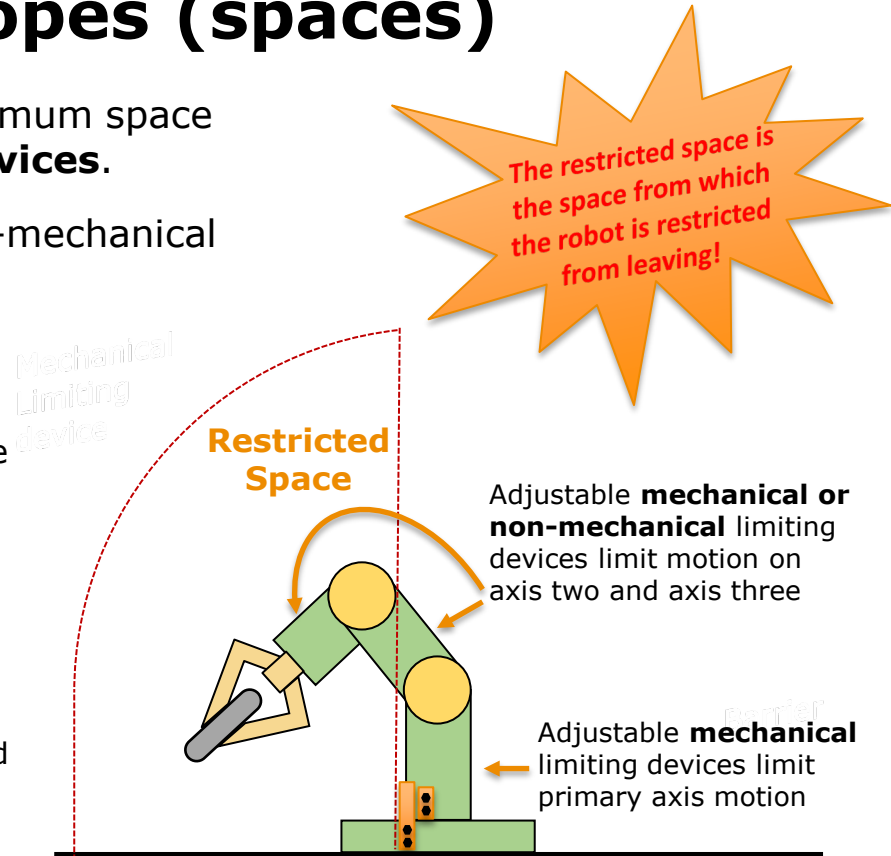


Industrial robot envelopes (spaces)

Restricted space – The portion of the maximum space to which a robot is restricted by **limiting devices**.

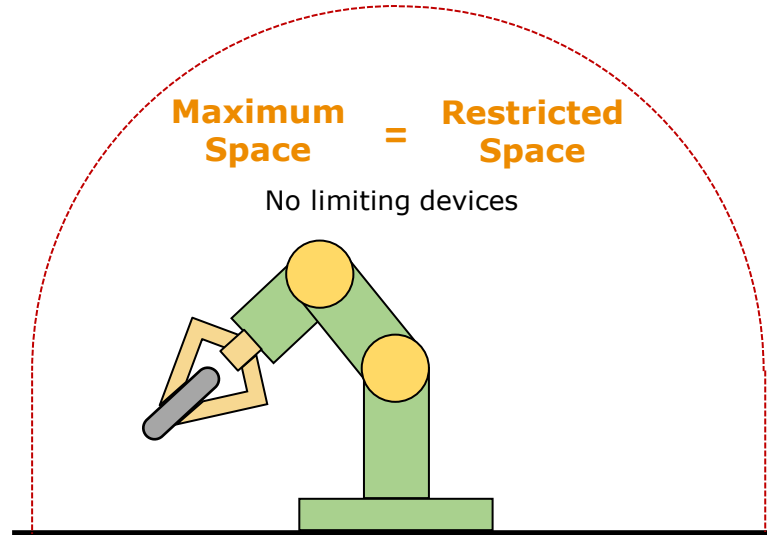
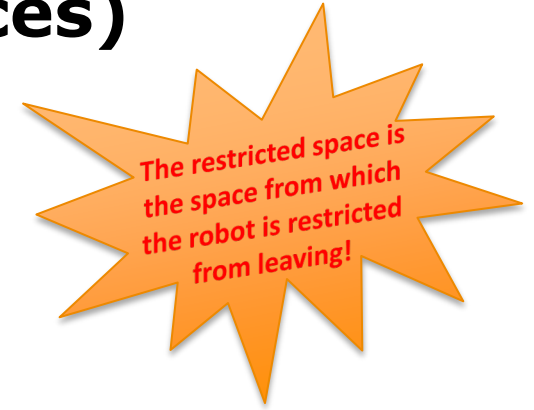
Limiting devices can be mechanical or non-mechanical

- **Mechanical** limiting devices include mechanical stops that are adjusted and then secured with fasteners
- **Non-mechanical** limiting devices include but are not limited to
 - Mechanical stops that are positioned electrically, pneumatically, or hydraulically,
 - limit switches,
 - light curtains,
 - laser scanning devices, and
 - pull cords that limit travel and define the restricted space



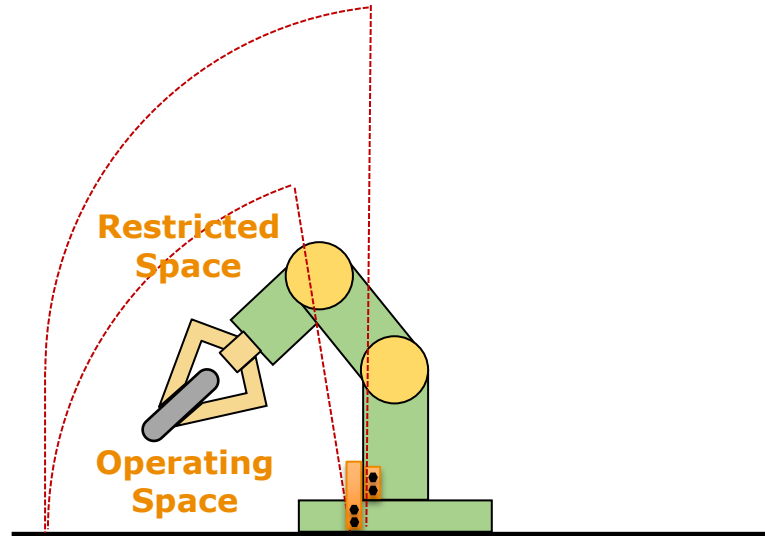
Industrial robot envelopes (spaces)

Maximum space = Restricted space – If the robot is not restricted to a portion of the maximum space by limiting devices.



Industrial robot envelopes (spaces)

Operating space – The portion of the restricted space that is used by the robot.



The restricted space is the space from which the robot is restricted from leaving!

3. Some hazards

Some hazards

Physical risks associated with unintended movement of industrial robots

- The robot moves when it wasn't expected to move
- The robot doesn't move the way it was expected to move

Programming risks (i.e., errors and failures) can also result in unintended movement.

Hazards can be grouped into the following major types:

Impact, Collision, or other Struck-by / Caught-between

Hydraulic

Crushing and Trapping

Pneumatic

Struck-by Projectiles

Slipping, Tripping, and Falling

Electrical

Environmental

Refer to the OSHA Technical Manual

- The OTM provides technical information about hazards and controls to OSHA Compliance Safety and Health Officers
<https://www.osha.gov/otm>
- Chapter 4 addresses industrial robots
<https://www.osha.gov/otm/section-4-safety-hazards/chapter-4>

4. Some hazard controls

Some hazard controls

Step 1 – Consider the robot's maximum space

- How far could the robot reach if it had no limiting devices?



Some hazard controls

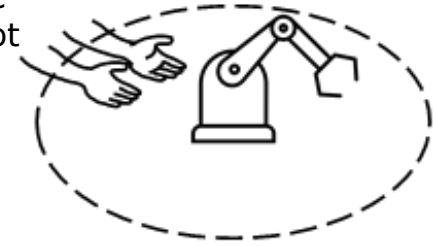
Step 1 (continued) – Consider the robot's maximum space

- A person might be injured if they enter the maximum space **fully** or **partially**.

e.g., **full-body** entry into the maximum space of a relatively large robot



e.g., **partial-body** entry into the maximum space of a relatively small robot



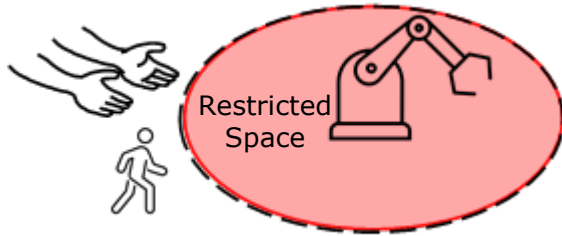
- The risk of being injured can be reduced by:
 - Controlling entry into the maximum space, or
 - Restricting the robot to a portion of the maximum space and then controlling entry into the **restricted space**.



Some hazard controls

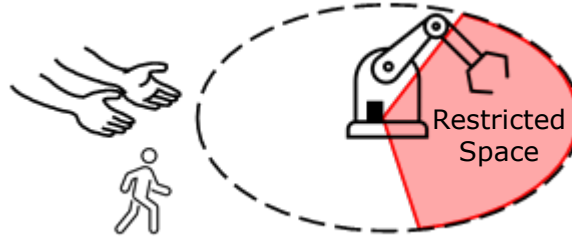
Step 2 – Establish the robot's restricted space

No limiting devices installed



Maximum Space

Limiting devices installed



Maximum Space

The restricted space is the space from which the robot is restricted from leaving!

- Use manufacturer's limiting devices
- Install the limiting devices in accordance with the manufacturer's instructions
- Verify limiting devices restrict robot motion as intended

Some hazard controls

Step 3 – Minimize the size of the restricted space within the robot's maximum space

- May reduce the probability of a person entering the restricted space inadvertently
- May reduce the frequency of needing to enter the restricted space purposefully



The restricted space is the space from which the robot is restricted from leaving!

Some hazard controls

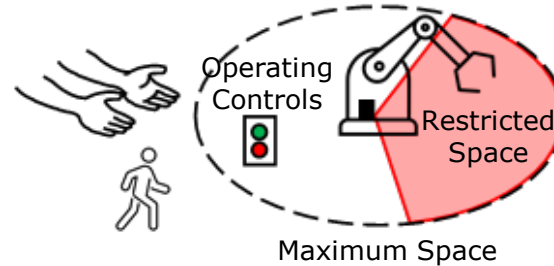
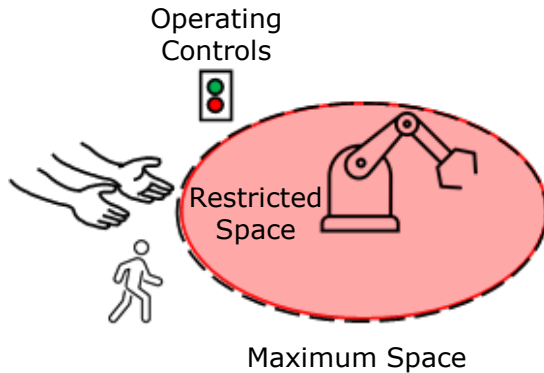
Step 4 – Conspicuously identify the restricted space

- Conspicuously identify the maximum space as the restricted space if the restricted space is not otherwise conspicuously identified.
- Active presence-sensing devices or active barriers can be used to identify the restricted space if they're conspicuous and their locations are outside of the restricted space.
- Passive perimeter guarding, awareness barriers, and awareness signals can be used to identify the restricted space if they're conspicuous and their locations are outside of the restricted space.
- Make all persons who need to recognize the restricted space aware of how it is identified.



Some hazard controls

Step 5 – Locate operating controls, requiring access during automatic operation, outside of the restricted space



The restricted space is the space from which the robot is restricted from leaving!

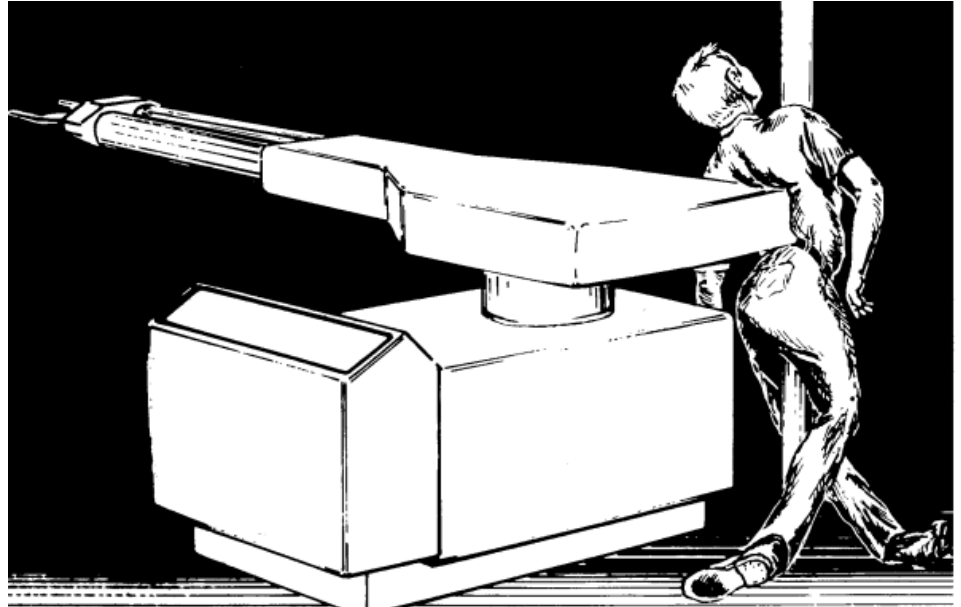
Some hazard controls

Step 6 – Avoid trap or pinch points

- Avoid creating trap or pinch points in the restricted space

What type of robot is this?
Hint – look at the year

Polar Robot (a.k.a. Spherical Robot)



From a **1984** NIOSH Alert

Some hazard controls

Step 7 – Safeguard the industrial robot system

- Conduct a risk assessment
- Identify appropriate and adequate safeguards
 - Means and degree of safeguards correspond directly to assessed risk.
- Means include: _____
 - Active presence-sensing devices
 - Active barriers
 - Passive perimeter guarding
 - Passive awareness barriers or signals
 - For “cobot” robots, include one or more of the “additional safety functions”
 - Safety-rated Monitored Stop (SMS)
 - Speed and Separation Monitoring (SSM)
 - Power and Force Limiting (PFL)
 - Hand-Guided Control (HGC)

Don't get caught up in terminology because the lines between these is not always clear.

Rather... focus on whether the means... whatever they are... correspond directly to the assessed risk.

That is, focus on whether the residual risk is acceptable.

These are described on the next 2 slides.



Industrial robots

“Cobots” – Additional safety functions

- Allow a person and a robot to interact in a collaborative workspace
- Are covered in the CSA, ANSI, and ISO standards and in the OSHA Technical Manual

1. Safety-rated Monitored Stop (SMS)

- The robot and the person can't move concurrently in the collaborative workspace
- Robot motion stops when the person is sensed entering the collaborative workspace
- Robot motion can resume automatically when the person exits the collaborative workspace

2. Hand-Guided Control (HGC)

- A safety-rated monitored stop is achieved then maintained until the person takes control of the robot with a hand guiding device located at or near the end effector
- The hand guiding device includes an enabling device (hold-to-run)

Industrial robots – "cobots"

"Cobots" – Additional safety functions

- Allow a person and a robot to interact in a collaborative workspace
- Are covered in the CSA, ANSI, and ISO standards and in the OSHA Technical Manual

3. Speed and Separation Monitoring (SSM)

- Robot motion may slow down, change direction, or stop if the separation distance decreases below a protective distance.
- When the robot's speed decreases the protective separation distance decreases correspondingly
- Robot motion resumes automatically when the person moves away from the robot

4. Power and Force Limiting (PFL)

- Contact between the robot and the person can occur intentionally or unintentionally
- Risk of injury is reduced by
 - inherently safe design, or
 - sensors and safety-related parts of the control system configured such that contact pressures and forces do not exceed acceptable limits.

Some hazard controls

Step 8 – Train all workers (including managers and supervisors) personnel to recognize the restricted space and how to safely avoid it or safely enter it as applicable

Step 9 – Write and implement **safe work procedures including lockout procedures** (when applicable) for authorized tasks including:

- Teaching the robot
- Attended continuous operation
- Maintenance with drive power required
- Maintenance without drive power required

Step 10 – Establish, as a **safe work practice**, that no person is to enter a robot's restricted space except for authorized tasks following applicable written procedure(s)

Step 11 – Install **isolating devices** outside the restricted space for de-energization and lockout

Step 12 – Install means for **controlled release** of stored energy

Some hazard controls

Step 13 – Provide a pendant control

- Facilitates controlling the robot from within the restricted space for authorized tasks

Must not be possible to place the robot into automatic mode using only the pendant control

Buttons that cause motion must also stop motion when released

- “Hold-to run”



When used, motion from other controls must be prevented

- “Single point of control”

Initiated motion must not exceed 25 cm/sec (10 in/sec)

- “Slow speed control”

5. Some key points

Some key points

1. The term “industrial robot” is defined in harmonized CSA, ANSI, and ISO standards
2. Industrial robots are used in many industries
3. A cobot is a robot designed for direct interaction with a human within a defined collaborative workspace
4. An industrial robot’s restricted space is the portion of the robot’s maximum space to which the robot is restricted from leaving
5. In controlling hazards
 - a. Establish and conspicuously identify the restricted space
 - b. Locate operating controls outside the restricted space
 - c. Avoid creating trap or pinch points in the restricted space
 - d. Safeguard the industrial robot with means and degree of safeguards corresponding directly to assessed risk
 - e. For cobots, include one or more of the additional safety functions
 - f. Train all workers (including managers and supervisors) to recognize the restricted space and how to safely avoid it or safely enter it as applicable
 - g. Write and implement safe work procedures, including lockout procedures (when applicable)
 - h. Establish a safe work practice of no restricted space entry except for an authorized task following a written procedure
 - i. Install isolating devices for de-energization and lockout
 - j. Install means for controlled release of stored energy
 - k. Provide a pendant control

Some key points

6. Be aware that industrial robots may be a hazard
 - a robot moving when movement isn't expected may contact and injure a worker
 - a robot moving in a way that isn't expected may contact and injure a worker
 - a robot contacting a worker may result in injury, serious injury, or death
7. Identify who is potentially at risk
8. Become knowledgeable regarding implemented hazard controls
 - What they are, where they are, how they function, who they protect... etc.
9. Develop a practical and safe way to regularly confirm the robot can't move beyond whatever is intended to conspicuously identify the restricted space boundaries
10. The potential for implemented hazard controls to erode may be high
 - Particularly when knowledge of implemented controls is limited to the persons who selected and implemented them
 - This is not unique to industrial robots.
11. The machinery or equipment that you have may not be an "industrial robot", but it may have the same or similar hazards, such that the same or similar safeguards are required.

End