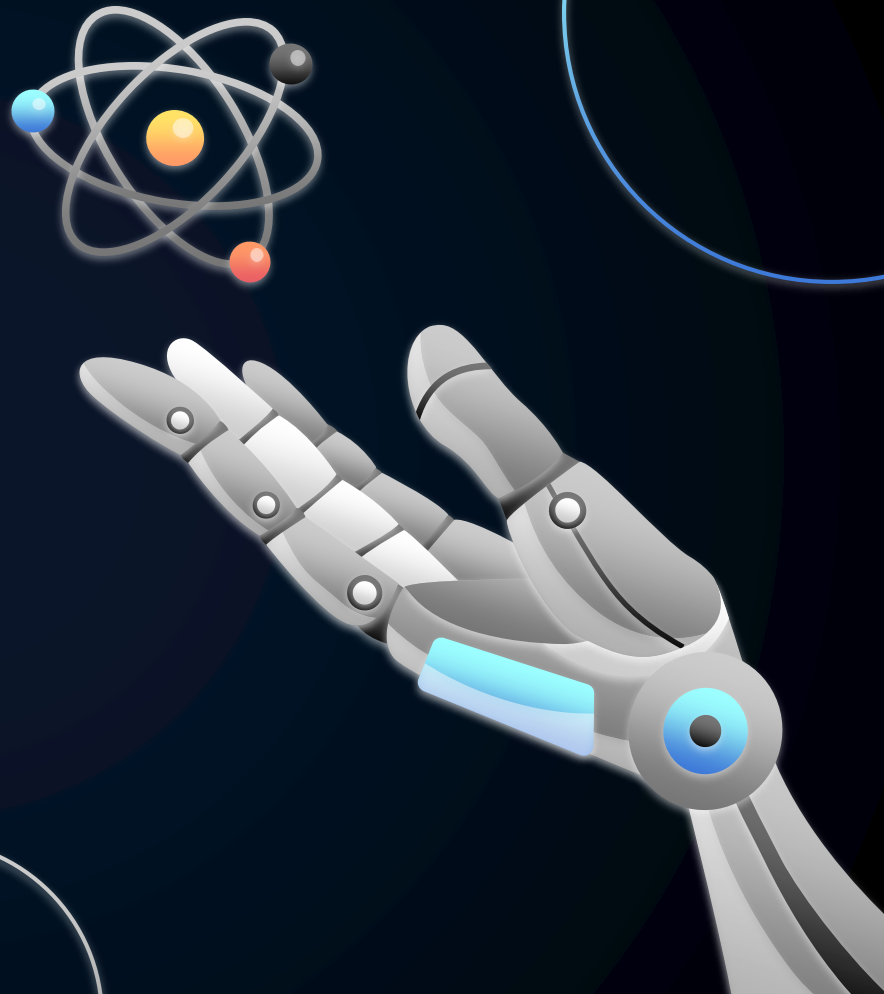
Robotics and Automation

On and Off the Stage

USITT Columbus 2025



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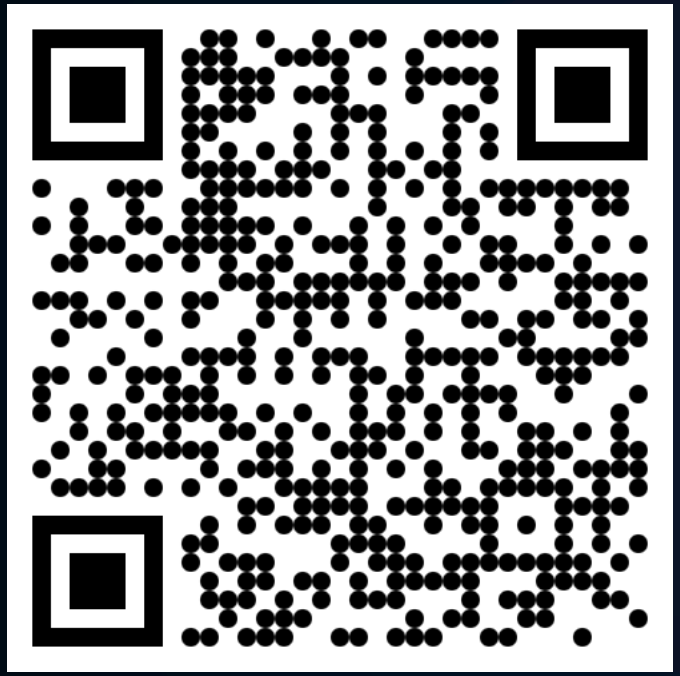

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Panel

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Disclaimer

The views and opinions expressed in this presentation are the panelists own and do not necessarily reflect the views, policies, or positions of our employers. This talk is a personal endeavor and should not be interpreted as an official statement or endorsement.

01

Robotics Concepts

Some Definitions

Robots

- Robot: programmed mechanism that actuated with a level of autonomy to interact with the physical world
- Robotic Arm: mechanical arm operating under computer control
- Mobile Robot: a robot that can travel under its own control

Top: Kuka Robotic Arm
Bottom: Clearpath Mobile Robot

Combine them!

Released with: LA-UR-25-21505

Robotic Arm

- Degrees of Freedom (DOF): Number of joints (axises)
- Joints: rotary or linear
- Workspace: the volume the manipulator can reach
- End-effector: device at the end of the arm to interact with the world around it
- TCP: Tool Center Point

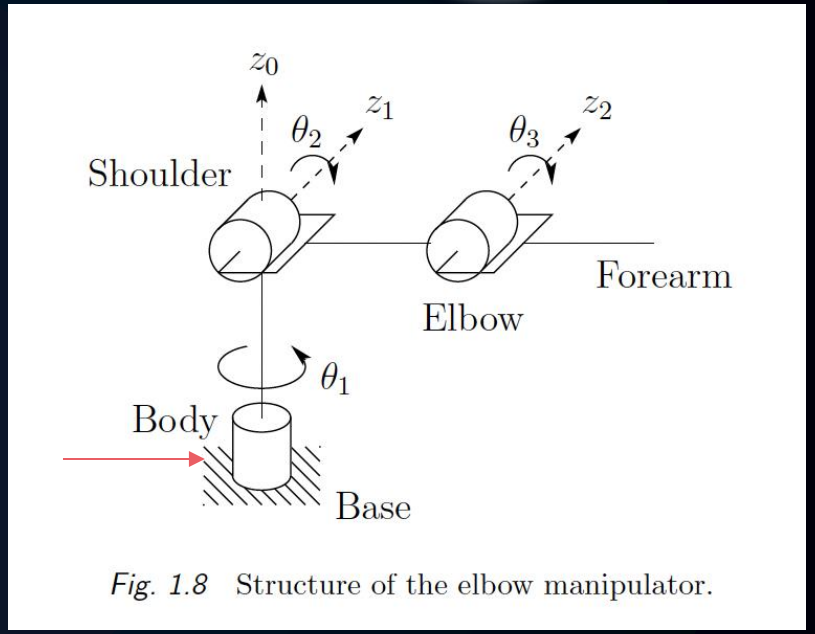


Fig. 1.8 Structure of the elbow manipulator.

Be Scared

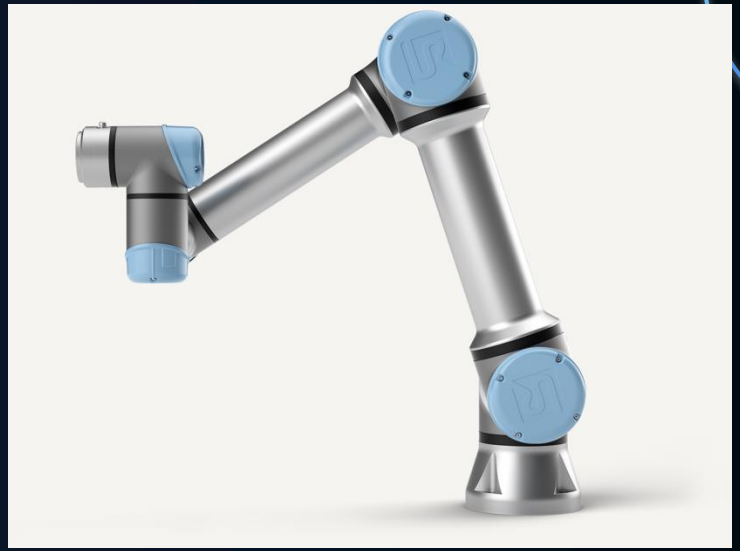
Robots will do exactly what they are told
Can lift cars
Will run into you

Collaborative Robots (Cobot)

Designed to work along side humans

Pros:
More sensors
Lower forces present

Cons:
Smaller
Lower Capacity



Universal Robotics UR5 Cobot

02

Creative Questions

Questions When Deciding to Automate Scenery

How Heavy?

How Fast?

How Far?

What if we want a Robot Performer?

How fast does a performer move?

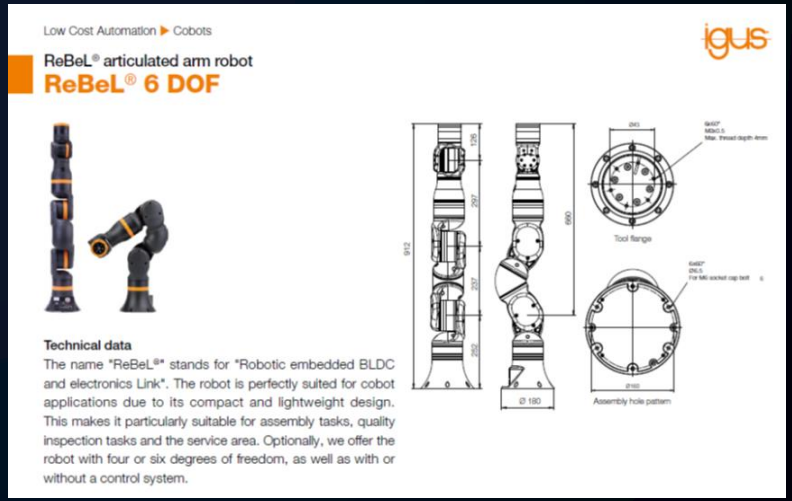
To spin like a ballerina, or a figure skater?

Throw a fastball?

Barriers to Achieving a COBOT Performer?

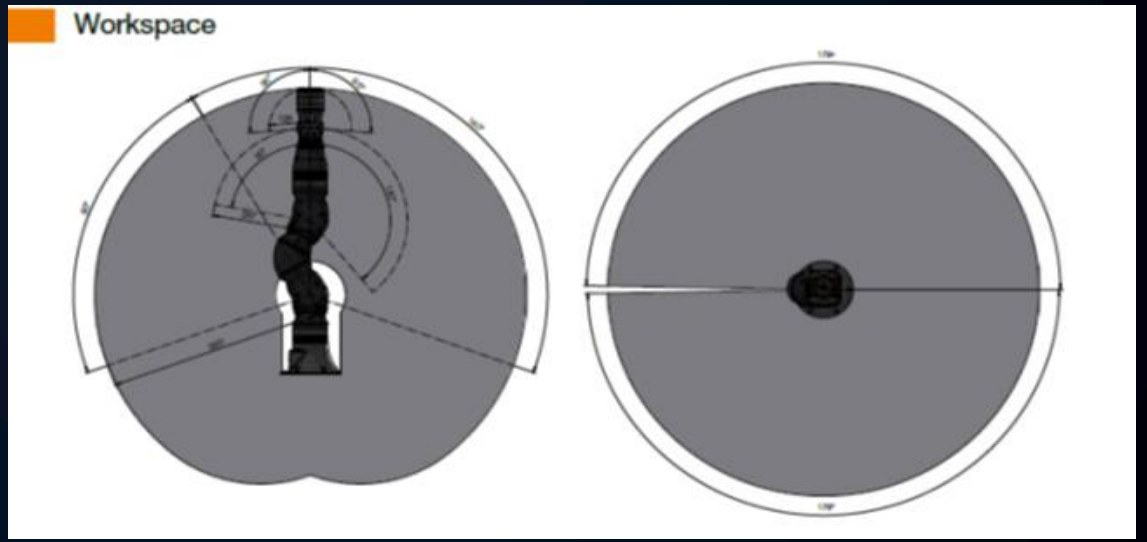
Capability, Size, and Cost of the Machine.

4 Pound Payload
45 Degrees Per Second
2 Feet of Reach



Working Envelope of a COBOT Arm

358 Degrees
In Plan



03

Safety

Industrial Robot Safety Standards

Robots and Robotic Devices

ISO 10218-1:2011 – Safety Requirements for industrial robots – Part 1: Robots

ISO 10218-2:2011 – Safety Requirements for industrial robots – Part 2: Robot system and integration

ISO/TS 15066:2016 – Collaborative robots

ISO 10218: A Bifurcated Standard

ISO 10218-1 & ISO 10218-2

- ISO 10218-1 provides guidance for the assurance of safety in the design and construction of the robot.
- ISO 10218-2 provides guidance for the safeguarding of personnel during robot integration, installation, functional testing, programming, operation, maintenance, and repair.

Similar to ANSI E1.6-2 & ANSI E1.6-3

- ANSI E1.6-2 covers the design, inspection, and maintenance of serially manufactured electric link chain hoist for the entertainment industry
- ANSI E1.6-3 establishes minimum safety requirements for the selection and use of serially manufactured electric link chain hoists in the entertainment industry.

ISO/TS 15066: Specific Use Case

- ANSI E1.43 is a specific usage case of ANSI E1.6-1 & ANSI E1.4-1

- ISO/TS 15066 provides additional guidance on the collaborative requirements of ISO 10218.

- But..
  - E1.6-1 and E1.4-1 specifically exclude Performer Flying

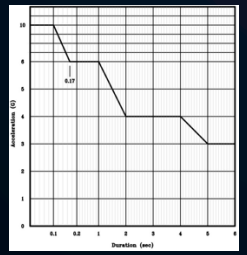
  - ISO/TS 15066 expands and clarifies Collaborative Robot Operations

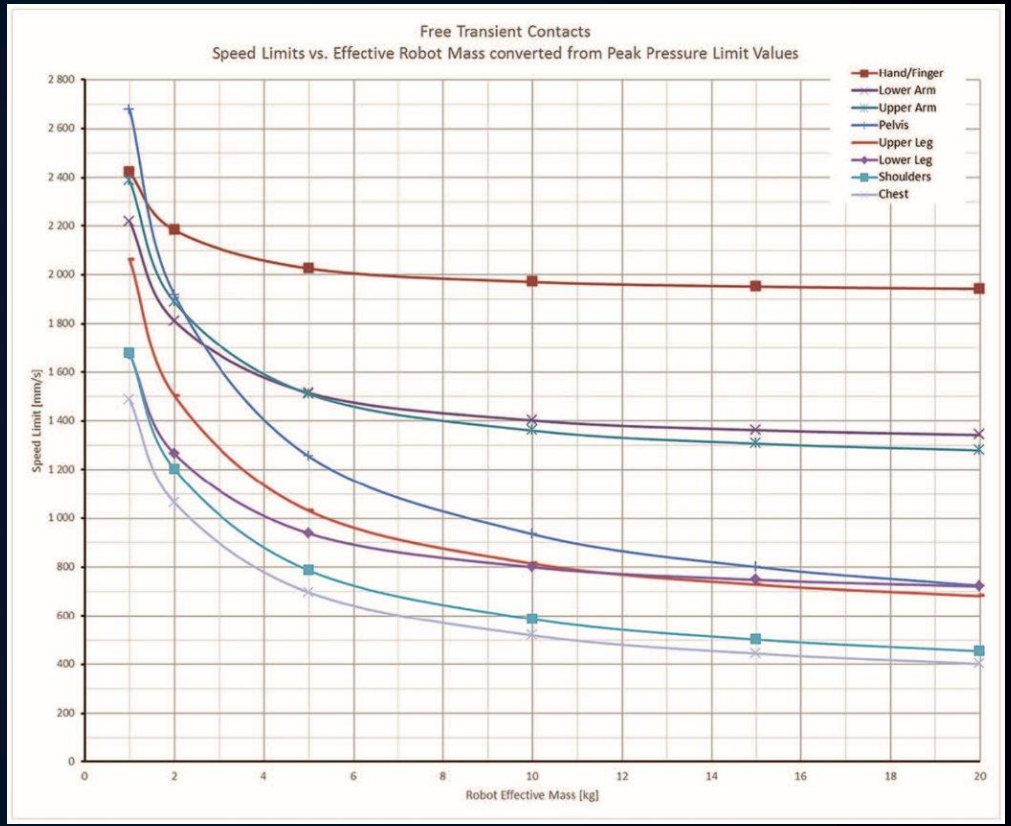
- ISO/TS 15066 allows close proximity to collaborative robots with one or more of the following methods:
  - Hand Guiding
  - Speed and Separation Monitoring
  - Power and Force Limiting

Further ANSI E1.43 and ISO/TS 15066 Similarities

- Impacts of systems on the human body
  - E1.43: Time based Acceleration (G) limits based on orientation
  - ISO/TS 15066: speed, separation, force, and pressure limits based on body contact region
    - Allows close proximity in collaborative operations
  - RIA TR R15.806: A Guide to Testing Pressure and Force in Collaborative Robot Applications

Example E1.43 Graph





ISO/TS 15066: Free Transient Contacts Graph

US National Adoption & More

ANSI/RIA R15.06-2012
USA National adoption of ISO 10218-1:2011 and 10218-2:2011

RIA TR R15.606
USA National adoption of ISO/TS 15066:2016

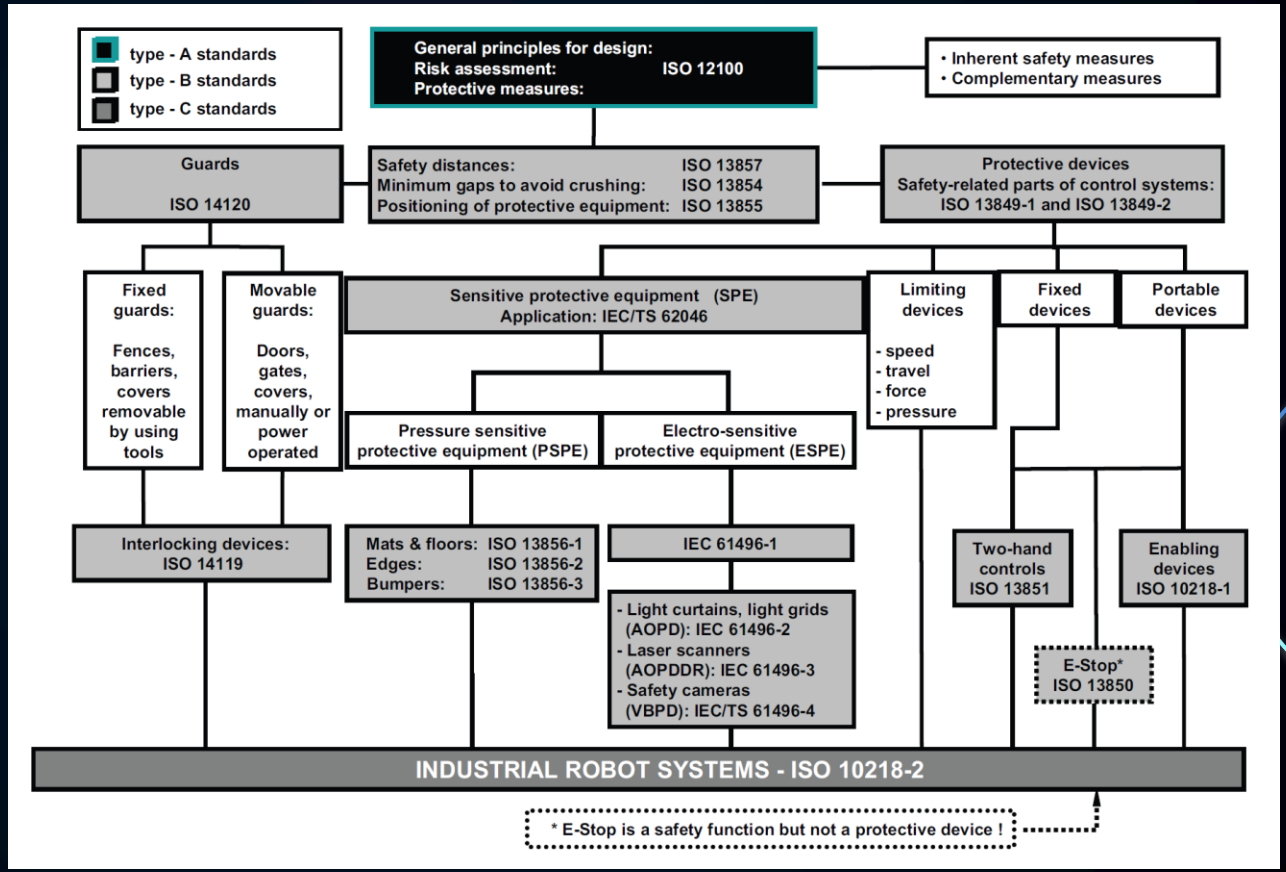
And a helpful additional resource:

- RIA TR R15.806 ("TR 806"): Testing Methods for Power & Force Limited Collaborative Applications.

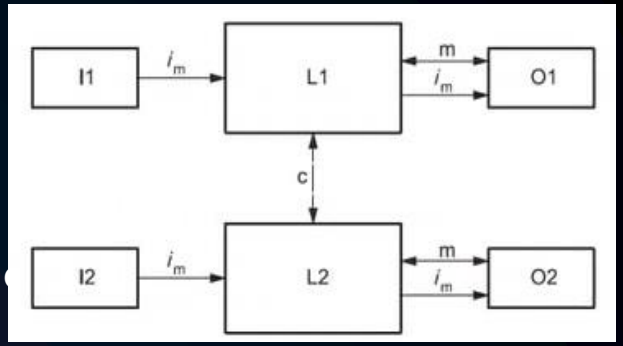
Describes methods to test and verify that the forces exerted by a collaborative robot system remain within the allowable limits described in TR 606 (ISO/TS 15066)

Similar General Format to ESTA standards

- Scope
- Normative References
- Terms and definitions
- Hazard identification & risk assessment
- Requirements
- Documentation
  - (Information for use)



Safety System Requirements



ISO 13849-1:2006: PL=d with structure category 3

Or IEC 62061:2005: SIL 2 with hardware fault tolerance (
(proof test interval of not less than 20 years):

a) a single fault in any of these parts does not lead to the loss of the safety function;

b) whenever reasonably practicable, the single fault shall be detected at or before the next demand upon the safety function;

c) when the single fault occurs, the safety function is always performed and a safe state shall be maintained until the detected fault is corrected;

d) all reasonably foreseeable faults shall be detected.

The requirements a) to d) are considered to be equivalent to structure category 3 as described in ISO 13849-1:2006.

Interesting Breakdown of Safety Terms

- 5.3.8.1 Robot System and cell stopping functions (General)

  - Every robot system or cell shall have a
    - protective stop function and
    - an independent emergency stop function.

  - The respective functions shall have the ability for the connection of additional protective or emergency stop devices.
  - Both shall stop all robot motion and other hazardous functions

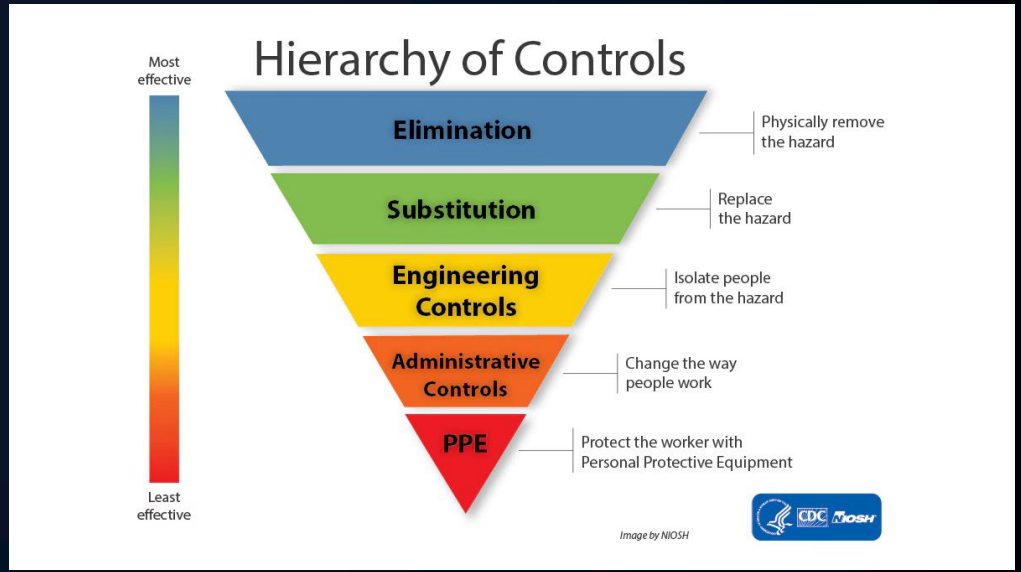
Emergency Stop: Manually initiated.

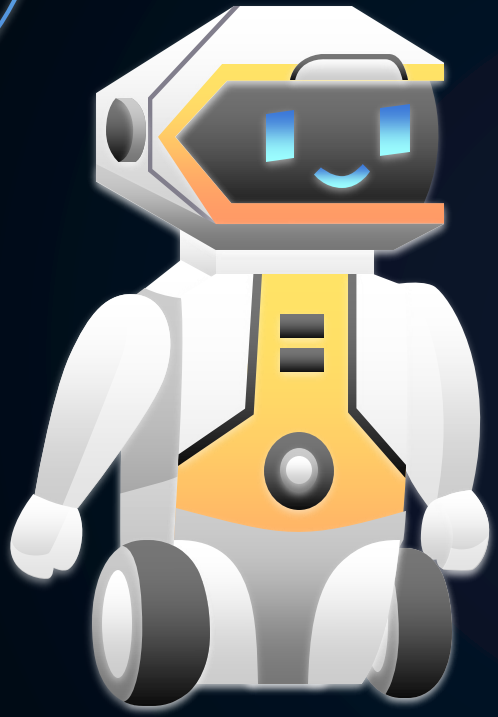
Protective Stop: May be initiated manually or by control logic.

Hazard Identification & Risk Assessment

- Utilizes ANSI/ISO 12100

No.	Type or group	Example of hazards		Subclause reference
		Origin	Potential consequences	
1	**Mechanical hazards**	— movements of any part of the robot arm (including back), end-effector or mobile parts of robot cell — movements of external axis (including end-effector tool at servicing position) — movement or rotation of sharp tool on end-effector or on external axes, part being handled, and associated equipment — rotational motion of any robot axes — materials and products falling or ejection — end-effector failure (separation) — loose clothing, long hair — between robot arm and any fixed object — between end-effector and any fixed object (fence, beam, etc.) — between fixtures (falling in); between shuttles, utilities — impossibility of exiting robot cell (via cell door) for a trapped operator in automatic mode — unintended movement of jigs or gripper — unintended release of tool — unintended movement of machines or robot cell parts during handling operations — unintended motion or activation of an end-effector or associated equipment (including external axes controlled by the robot, process specific for grinding wheels, etc.) — unexpected release of potential energy from stored sources	— crushing — shearing — cutting or severing — entanglement — drawing-in or trapping — impact — stabbing or puncture — friction, abrasion — high-pressure fluid/gas injection or ejection	4.1; 4.2; 4.2 d) 6); 4.2 f); 4.3; 4.4; 4.4.1; 4.4.2 d); 4.4.2 f); 4.5; 5.2; 5.2.1; 5.2.2; 5.2.3; 5.3; 5.3.2; 5.3.6; 5.3.7; 5.3.8.2; 5.3.9; 5.3.10; 5.5.1; 5.5.2; 5.5.3; 5.5.4; 5.6.4; 5.8; 5.9; 5.10.2; 5.10.3; 5.10.6.1; 5.10.6.2; 5.10.6.4; 5.10.7; 5.11; 5.11.4; 5.11.5.4



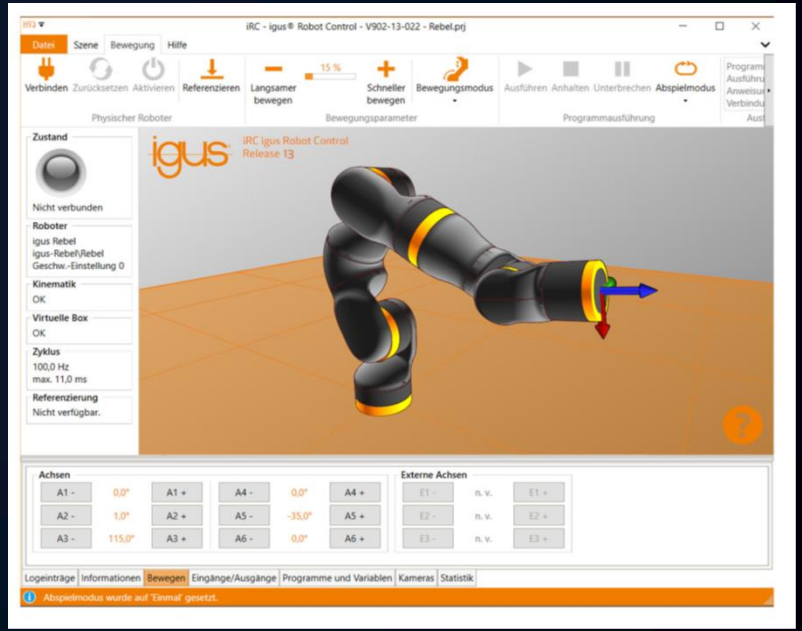


04

Implementation and Control

How to Talk to the Robot?

Control of Robot is Typically Focussed on the End Attachment.



How to Talk to the Robot?

Define Position of End Attachment

Joint by Joint Movement

Can you Jog with a Keyboard or Game Controller

How To Integrate a ROBOT ARM

Know the Story to be told
Get the Robot in Rehearsal
Keep It Safe
Interact With the Robot

Also, does the Robot Performer:

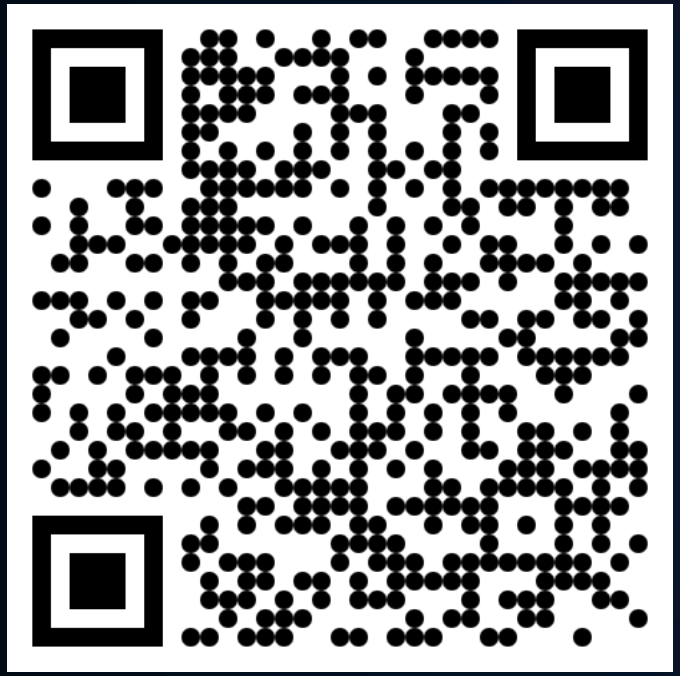
Move around stage?

Enter and exit?

05

Q & A

Presentation Link



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