# Introduction to Safety for Collaborative Robotics

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**Robotic Industries Association**

# Collaborative Robotics

## What is it ??

# Collaborative Robotics

## What is it ??

- Aren't "Collaborative" Robots safe "right out of the box"?
- It's "Collaborative" and that means "inherently safe" – right?
- Because it's "Collaborative" I won't need any of those safety fences and light curtains – right?

# Safety For Collaborative Robotics

## Why do we need this presentation?

# Safety For Collaborative Robotics

## Why do we need this presentation?

- Aren't "Collaborative" Robots safe "right out of the box"?
- It's "Collaborative" and that means "inherently safe" – right?
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**MYTHS**

**(OR AT LEAST, MISUNDERSTANDINGS)**

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# Safety For Collaborative Robotics

## Today's Topics:

- About Standards
- RIA's Foundational Standard: Safety Requirements for Industrial Robots and Robot Systems
- New Guidance on Collaborative Robot System Safety
- Resources

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# What Is A Standard?

**Voluntary Industry Consensus Standards**

- National and International Standards Organizations
- **ANSI, ISO,** IEC, ASTF, etc.
- Standards help create, grow, and stabilize markets


# Safety For Collaborative Robotics

## Today's Topics:

- About Standards
- **RIA's Foundational Standard:**
  Safety Requirements for Industrial Robots and Robot Systems
- Additional Guidance on Collaborative Robot System Safety
- Resources

# RIA's Standard: Industrial Robot Safety


**ANSI/RIA R15.06-2012,**
**Industrial Robots**
**&**
**Robot Systems –**
**Safety Requirements**

- U.S. National Adoption of ISO 10218-1,2:2011
  - 10218 Part 1: Safety Requirements for Industrial ROBOTS
  - 10218 Part 2: Safety Requirements for Industrial ROBOT SYSTEMS and Systems Integration

# RIA's Standard: Industrial Robot Safety

**R15.06 = 10218**

*= CSA Z434*
*etc.*

# Safety For Collaborative Robotics

**Why do we need this presentation?**

**Why do I need to know about the basic standard?**

- Aren't "Collaborative" Robots safe "right out of the box"?
- It's "Collaborative" and that means "inherently safe" – right?
- Because it's "Collaborative" I won't need any of those safety fences and light curtains – right?

# ...Because Collaborative Safety = TS 15066

- **ISO/TS 15066:2016** – an **ISO Technical Specification**
  - **RIA TR R15.606-2016** – An **ANSI-registered Technical Report**
  - Shorthand: “15066” or “TR 606”
- Order & download PDF from RIA Webstore
- **Important! Supplemental to ISO 10218 / R15.06**
  - “Industrial Robots and Robot Systems – Safety Requirements”

> “This Technical Specification is relevant only in conjunction with the safety requirements for collaborative industrial robot operation described in ISO 10218-1 and ISO 10218-2. ”

# Robot Definition from ISO 10218 / R15.06

- **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
  - NOTE 1: The industrial robot **includes**: the manipulator, including actuators; the controller, including teach pendant and any communication interface (hardware and software).
- **Industrial Robot System:** System comprising: Industrial robot; end-effector(s); any machinery, equipment, devices, external auxiliary axes or sensors supporting the robot performing its task

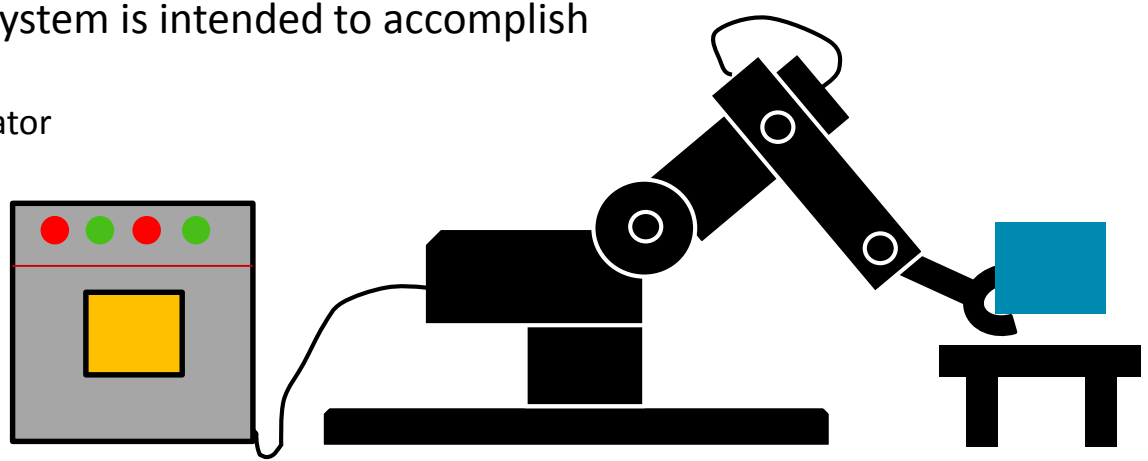
*Source: R15.06-2012, Part 1, Clauses 3.10 and 3.11*

# Robot Definition from ISO 10218 / R15.06

- **Industrial Robot** = Robot Arm + Robot Controller
- **Industrial Robot System** = Robot + End-Effector + Workpiece + Ancillary Equipment

  That make up a complete Robot ***System***

  - The End-effector and Workpiece are determined based on the **Application** – or, what the robot system is intended to accomplish
  - Might be a... ?
    - Sealant applicator
    - Gripper
    - Cutter
    - Welder
    - ...
    - ...



*Source: R15.06-2012, Part 1, Clauses 3.10 and 3.11*

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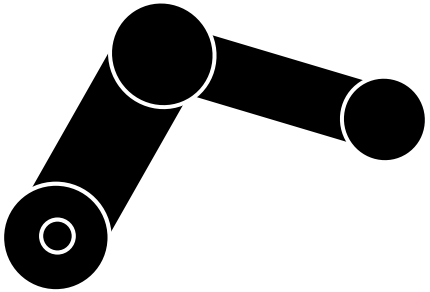
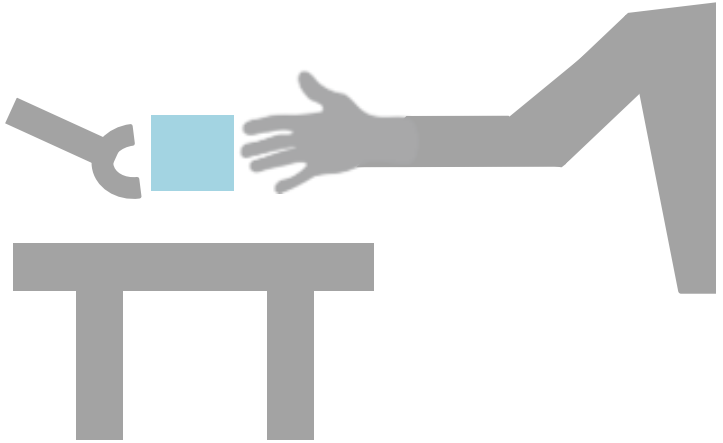
# Definitions: Robot

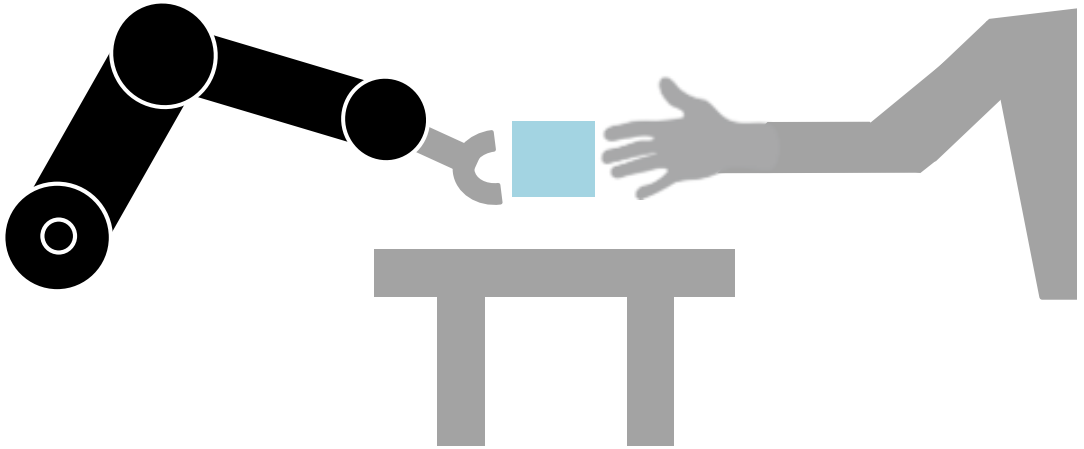


**“Collaborative” Robot**
*(PFL, “Inherently Safe,” etc.)*



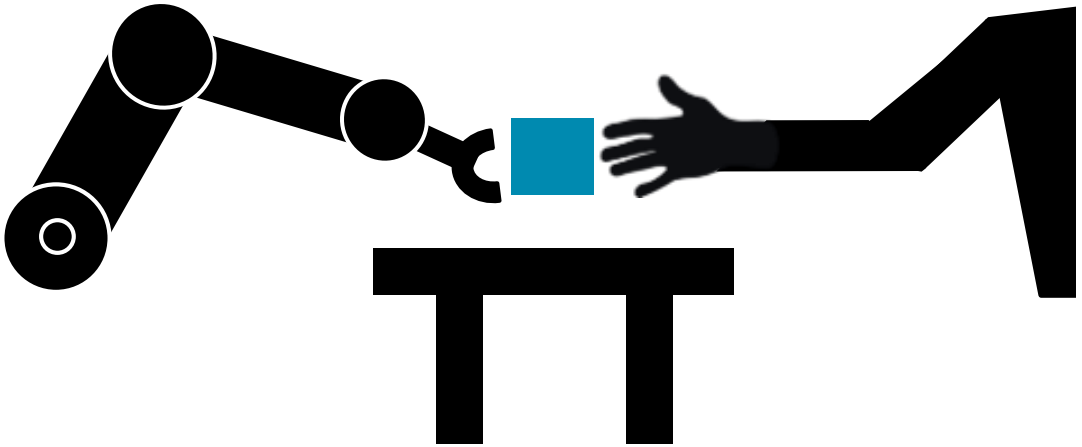
End-Effector, workpiece, ancillary equipment, etc.

# Definitions: Robot System



**Collaborative Robot SYSTEM**

# Definitions: Robot System



**Collaborative Robot SYSTEM**

# Safety For Collaborative Robotics

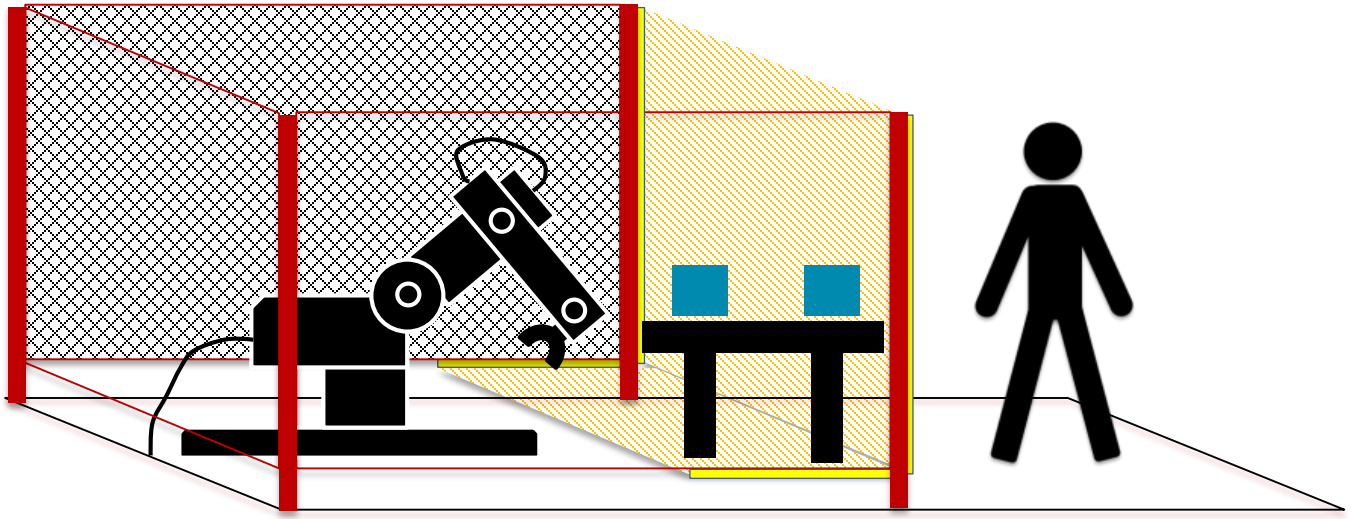
**MYTH** **Aren't "Collaborative" Robots safe "right out of the box"?**

**REALITY**

The "Collaborative" robot arm cannot do any work until it is integrated into a complete robot system – and it is the **ROBOT SYSTEM** that is (or is not) **COLLABORATIVE**

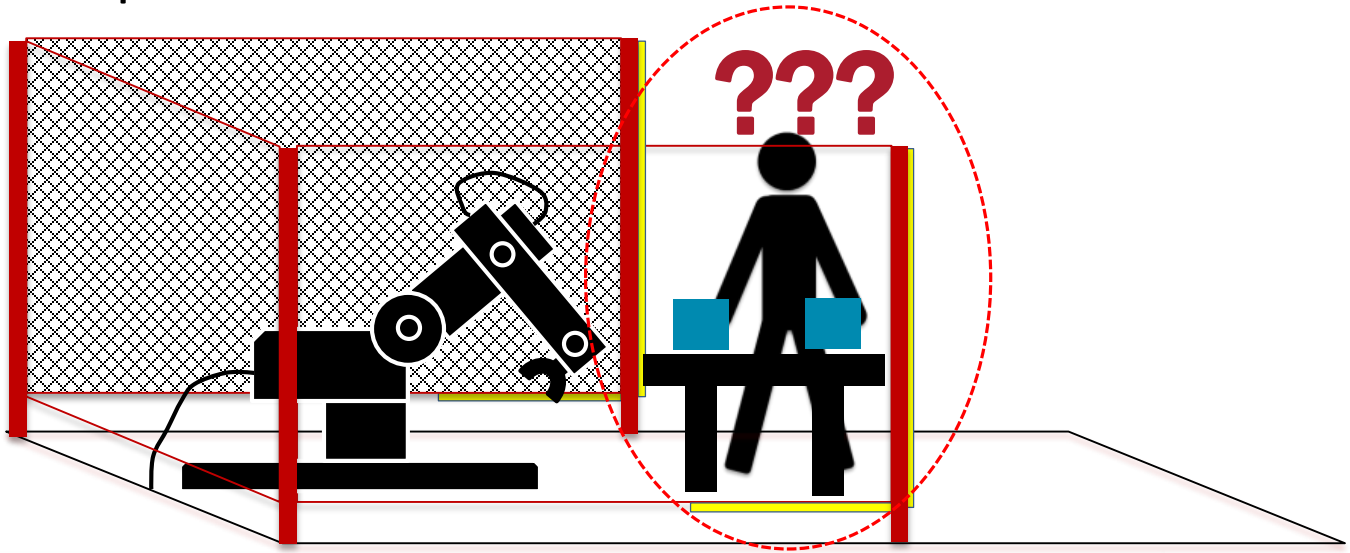
# Traditional Safety Paradigm

- **Old:** Primary means of protecting people was to separate them from the robotic equipment
- Physical safeguards and protective devices

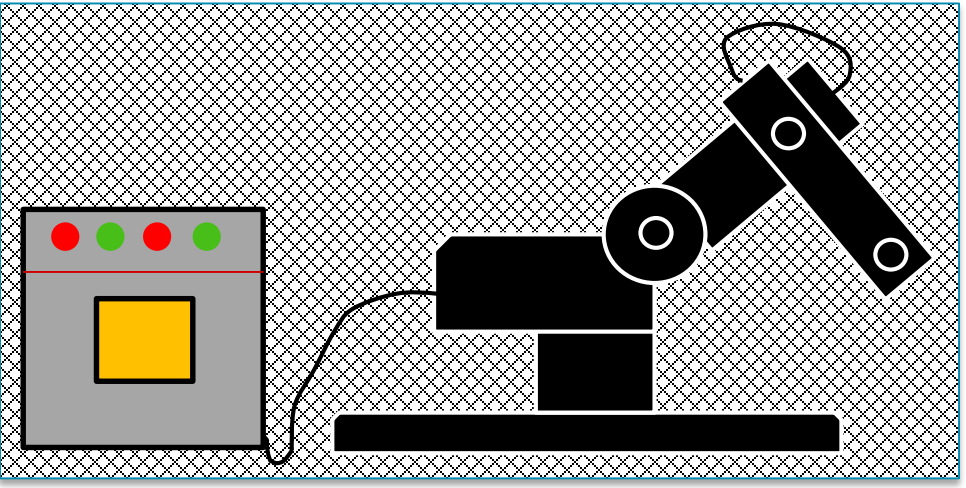


# Paradigm Shift

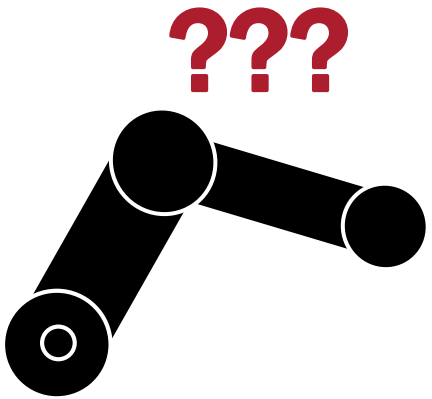
– **New:** With the advent of Collaborative Robot Systems, now the human and robot system can interact safely in the shared workspace



# Paradigm Shift



**“Traditional” Robot**
*(Safeguarded)*




**“Collaborative” Robot**
*(PFL, “Inherently Safe,” etc.)*

# Safety For Collaborative Robotics

MYTH

**It's "Collaborative" and that means "inherently safe" –**

**Right?**

REALITY

"Inherently safe" describes some specific design factors that help the robot arm be **safER** for human contact.

# “Inherently Safe” Design Factors

# Safety For Collaborative Robotics

## Today's Topics:

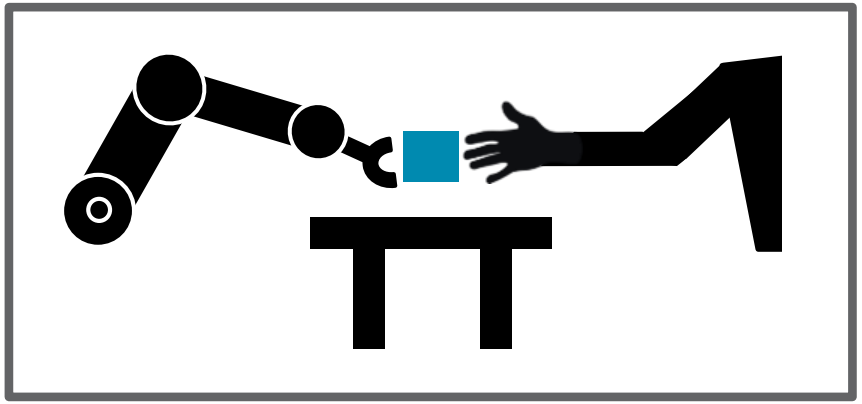
- About Standards
- RIA's Foundational Standard: Safety Requirements for Industrial Robots and Robot Systems
- **Additional Guidance on Collaborative Robot System Safety**
- Resources

# Why is TS 15066 / TR 606 Important?

Unique strengths of humans *(creative problem-solving)*

\+ Unique strengths of robot systems *(power and precision in repetitive tasks)*

**Increased productivity**



# Why is TS 15066 / TR 606 Important?

- Integrates **key information together** in one document:
  - Definition of collaborative robotic operation
  - Characteristics of safety-related control systems for collaborative operation
  - Factors for the design of a collaborative robot system*
  - Built-in safety-related systems for collaborative operation, and requirements for their use;
  - How to implement a collaborative application using the following techniques:
    - Safety-rated monitored stop
    - Hand guiding
    - Speed and Separation Monitoring
      - Guidance on speeds, protective distances, formula for protective separation distance*
    - Power and Force Limiting
      - Threshold limit values for power and force to avoid pain*

** New Information in 15066/ TR 606!*

# Why is TS 15066 / TR 606 Important?

**New information**:

- **Annex A:** "The Body Model" incorporates important data from a study of pain thresholds for Power and Force Limiting applications
- Study conducted at the University of Mainz in Germany
- 100 human test subjects; both sexes and wide range of ages and body dimensions
- Maximum permissible pressure values shown in Annex A represent the 75$^{th}$ percentile

*Sources: ISO/TS 15066:2016, Annex A;*
*http://www.dguv.de/ifa/fachinfos/kollaborierende-roboter/schmerzschwellenkataster/index-2.jsp*

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# Why is TS 15066 / TR 606 Important?

- **New information**:
  - **Annex A:** "The Body Model"

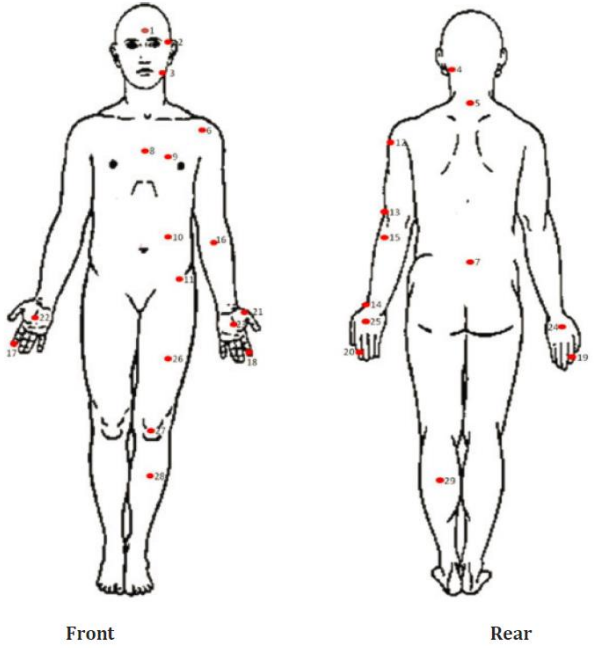


Figure A.1 — Body model

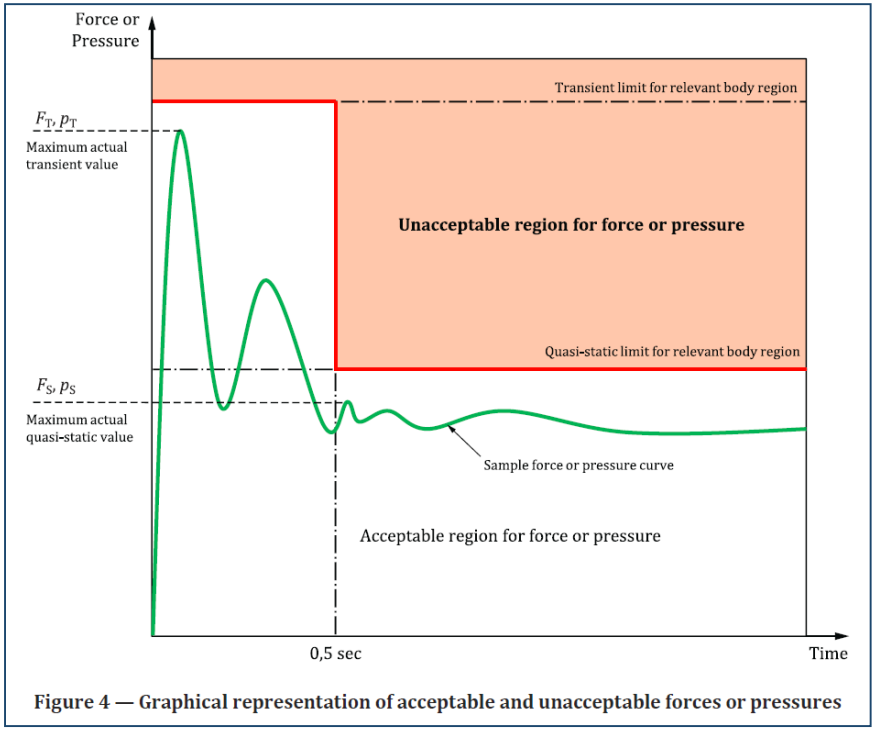


Figure 4 — Graphical representation of acceptable and unacceptable forces or pressures

*Source: ISO/TS 15066:2016, Fig. 4, Fig A.1*

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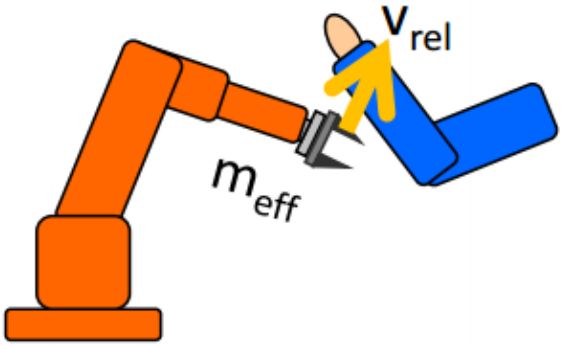
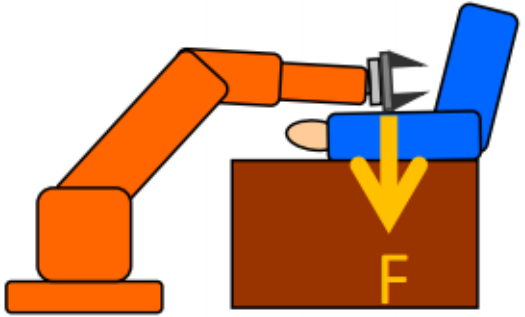
# Transient and Quasi-Static Contact




**Transient Contact:**
Human body part is capable of recoiling from impact

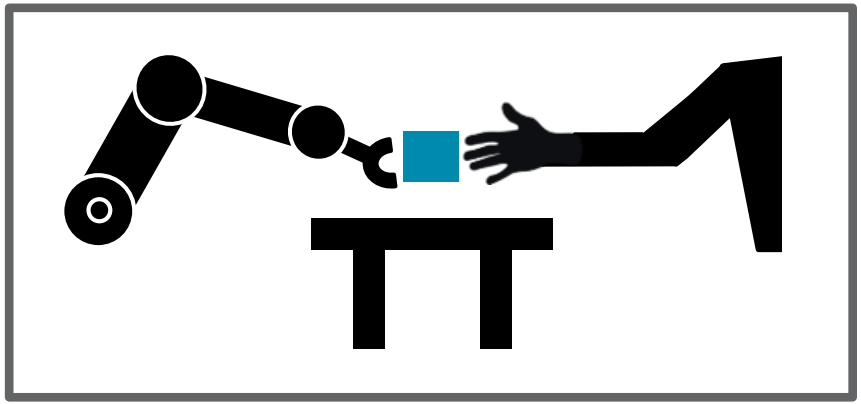



**Quasi-Static Contact:**
Human body part is at risk of being clamped or entrapped

*Source: ISO/TS 15066:2016.*
*Graphic Source: B. Matthias, NRSC 2015 Presentation. Used with permission.*

# How Can TS 15066 / TR 606 Help You?

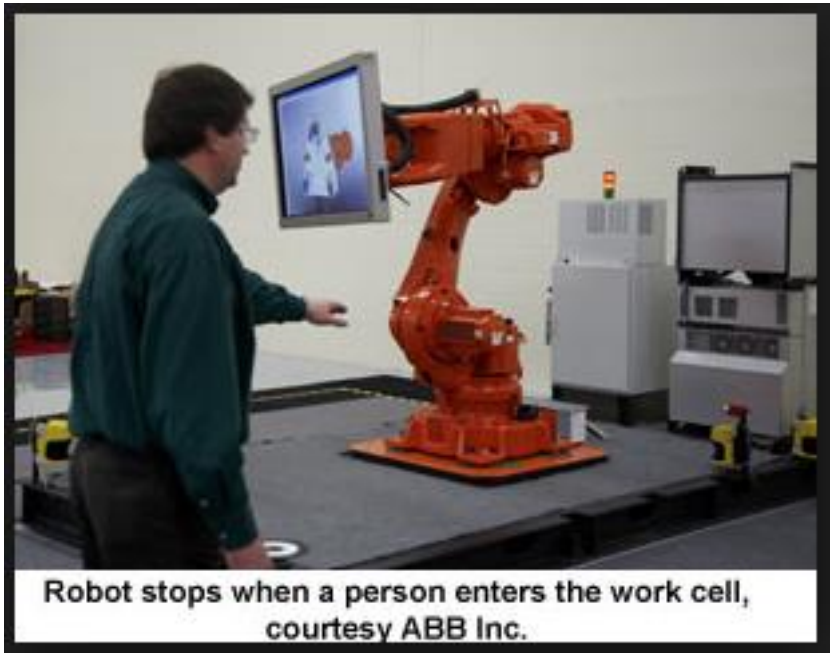
- Guidance primarily for suppliers and integrators for the safe design and operation of collaborative robot systems.
- Four types of collaborative operation:
  - Safety-rated monitored stop
  - Hand guiding
  - Speed and separation monitoring
  - Power and force limiting



# Four Types of Collaborative Operation (1)

## Safety-Rated Monitored Stop

- A stop is assured while maintaining power to the robot
- Operator may interact with robot
- Automatic operation may resume when the human leaves the collaborative workspace (requires safeguarding)
- Either the person OR the robot system may move, but NOT at the same time.



Robot stops when a person enters the work cell, courtesy ABB Inc.

# Four Types of Collaborative Operation (2)

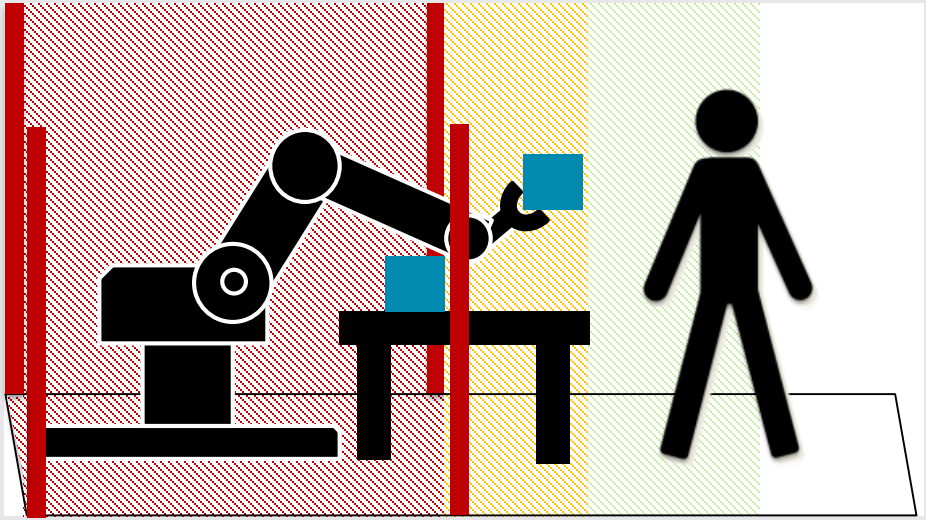
## Hand guiding

- Operator is in direct contact with the robot and is using hand controls to direct the robot where to go and what to do
- Robot system under manual control
- Both the person and the robot may move at the same time; motion controlled by the person

# Four Types of Collaborative Operation (3)

## Speed and separation monitoring

- Robot/hazard speed is reduced the closer an operator is to the hazard area
- Protective stop is issued when operator is in potential contact
- Person and robot may move at the same time



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# Four Types of Collaborative Operation (4)

## Power and force limiting

- Speed, torque, motion of the robot is controlled so that incidental contact between robot and operator will not cause harm
  - **Since contact is permitted, it must be controlled and its risks understood**
- Person and robot can move at the same time
- Possible risk reduction measures:
  - Robot design factors (e.g., rounded shape, compliant materials)
  - Appropriate application selection & robot cell design (e.g., end-effector, workpiece, motion path, etc.)
  - Consult biomechanical power and force guidance (Annex A)
    - Transient Contact (human body part can usually recoil or “bounce away”)
    - Quasi-Static Contact (clamping; entrapment risk)

# Four Types of Collaborative Operation

| Collaborative type | Benefit | High Risk Applications? | Low Risk Applications |
|---|---|---|---|
| **Safety-rated monitored stop** | Quicker resumption of operation (power retained) | **Yes** safeguarding required | **Yes** |
| **Hand-guided** | Personal control & responsibility by operator; high variability of programs & quick changes | **Yes** | **Yes** |
| **Speed & Separation Monitoring** | Reduced space for application; Immediate resumption of higher speeds | **Yes** safeguarding required for intrusion/ approach | **Yes** safeguarding required for intrusion/ approach |
| **Power & Force Limiting** *(without protective devices)* | Reduced space for application; if easy to program, then personal control by operator | **Yes, but LOW speed (might be VERY SLOW)** | **Yes** |

*Source: ISO/TS 15066:2016.*
*Graphic Source: R. Nelson Shea, NRSC 2016 Presentation. Used with permission.*

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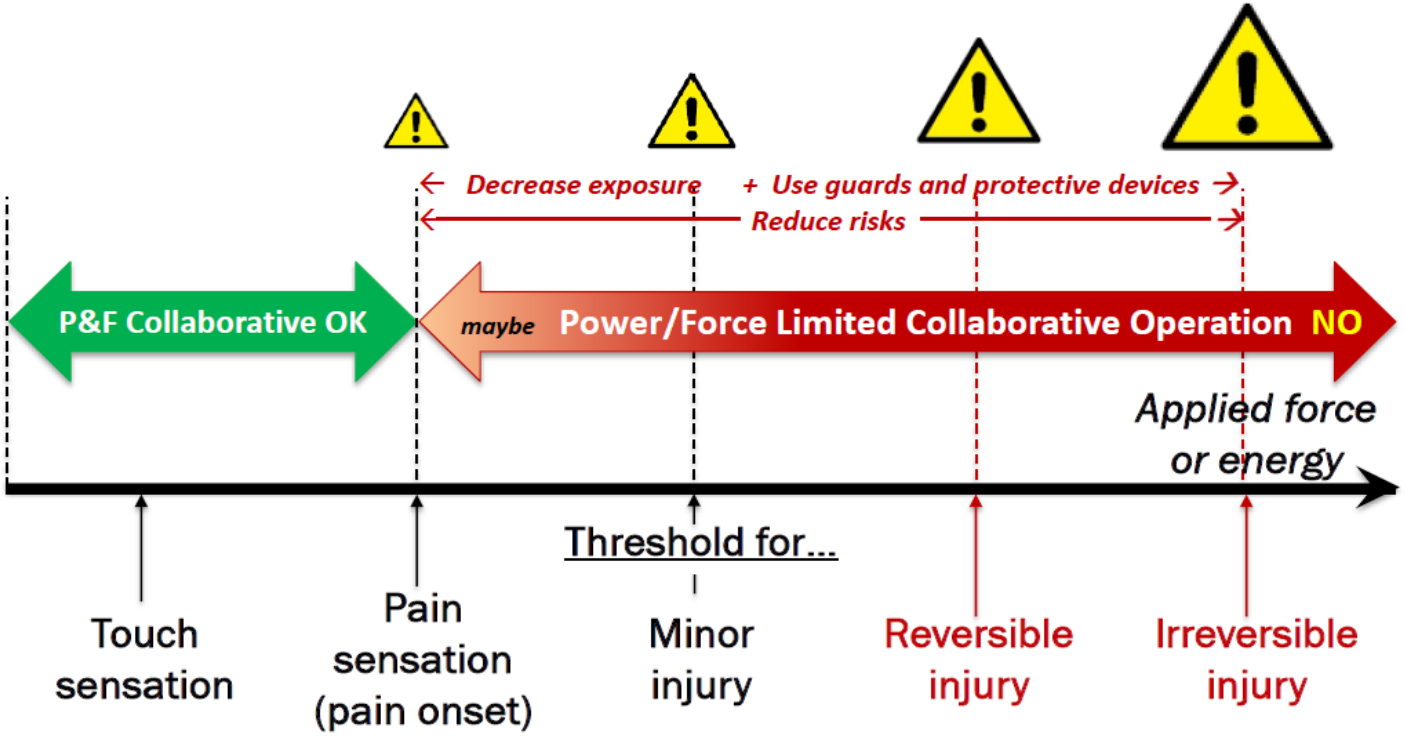
# Four Types of Collaborative Operation

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*Graphic Source: R. Nelson Shea, NRSC 2016 Presentation. Used with permission.*

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# Safety For Collaborative Robotics

MYTH **Because it's "Collaborative" I won't need any of those safety fences and light curtains –**

**Right?**

REALITY

Depending on your risk assessment (and yes, the RA is still required), you might find you do need **safeguarding**

# Safety For Collaborative Robotics

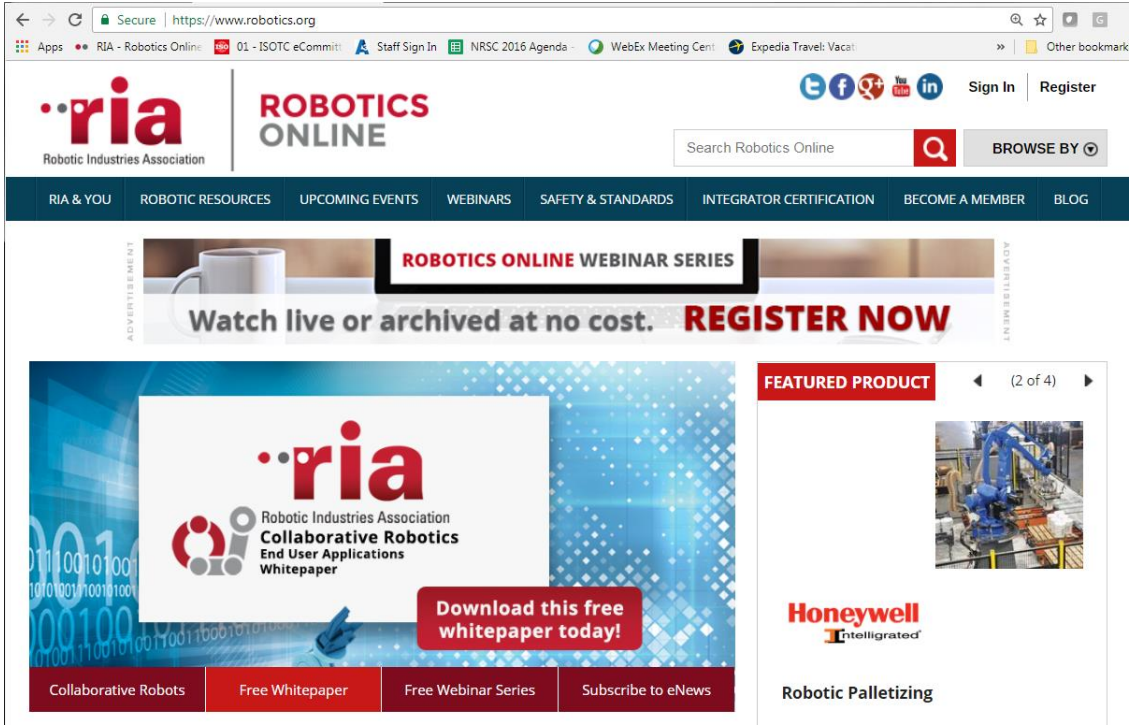
## Today's Topics:

- About Standards
- RIA's Foundational Standard: Safety Requirements for Industrial Robots and Robot Systems
- New Guidance on Collaborative Robot System Safety
- **Resources**

# Practical Steps for Collaborative Safety

1. **Get to know your Standards**
   - R15.06 / 10218; TR 606 / TS 15066
2. **Think in terms of the Robot SYSTEM**
   - Not just the robot arm!
3. **Select Other Equipment with Care**
   - Avoid end-effectors (etc.) that are sharp, pointed, jagged, hot...
4. **Do your Risk Assessment**
   - TR 306
5. **Watch your Poses and Paths**
   - Avoid those that might cause contact with face/ head/ neck, or clamping/ pinching (quasi-static contact)

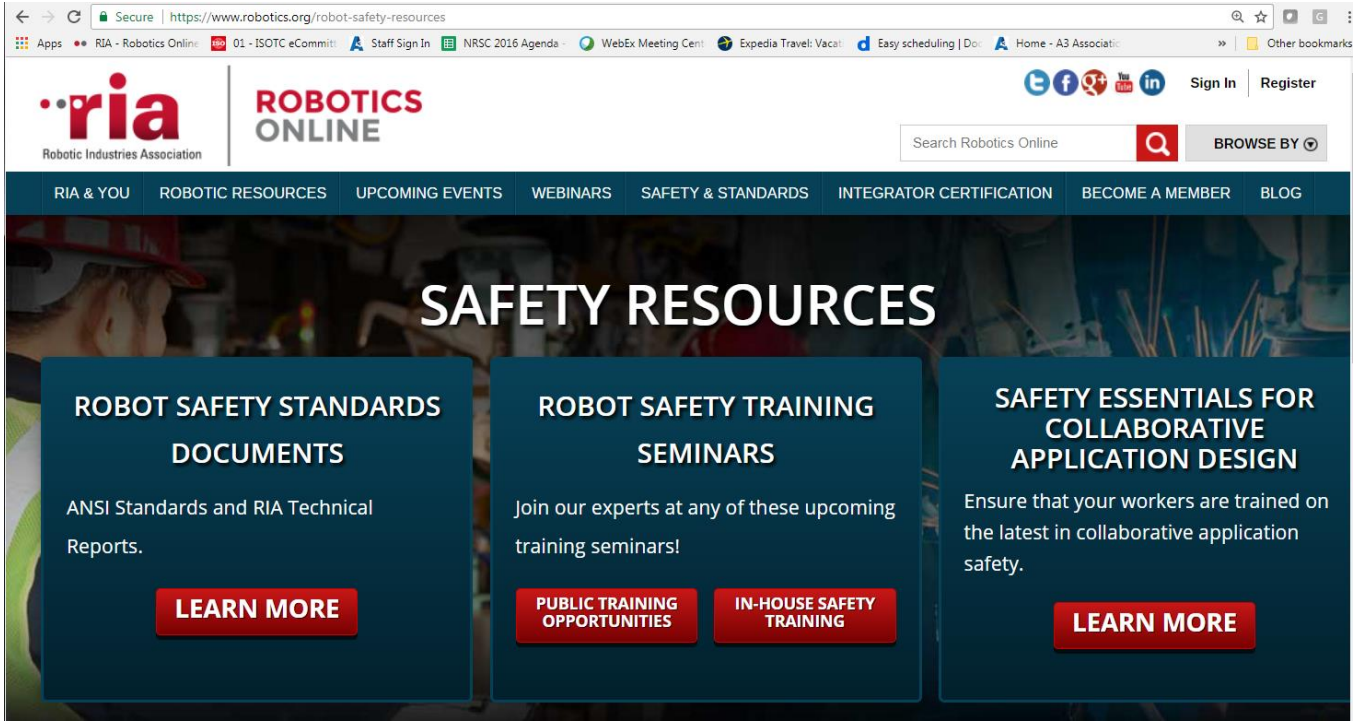
# Resources: Robotics.org




- Feature Articles
- Safety Resources
- Webinars
- Supplier Information
- Certified Integrators Program
- Industry Event Schedule
- More!

# Resources: Robotics.org/ CRAV.ai

# Resources: Robotics.org/ Safety Page




- Standards Documents
- Safety Seminars
- Webinars
- Risk Assessment Software

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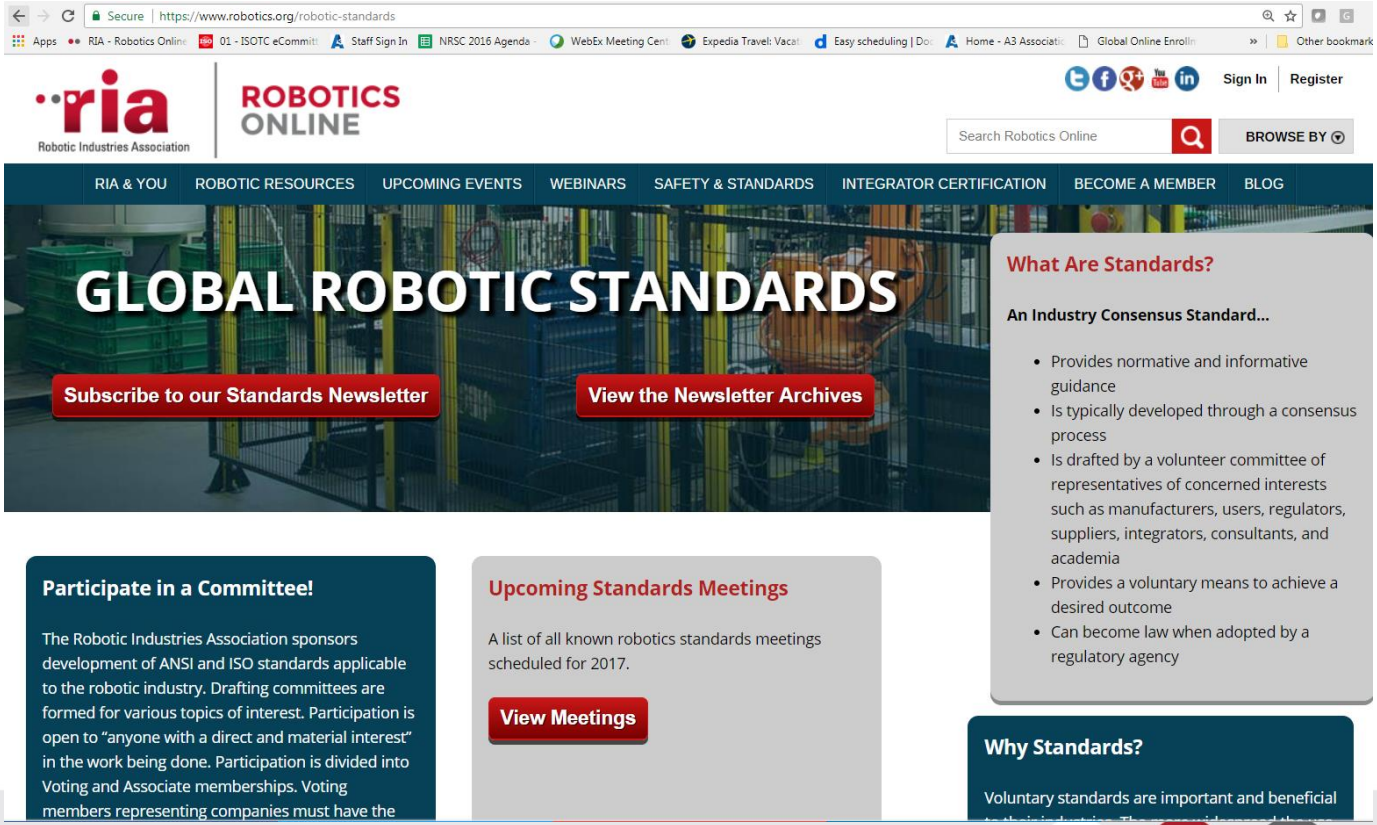
# Resources: Robotics.org/ Standards




- Standards Newsletter
- Upcoming Standards Meetings Schedule
- Committee Application

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# Questions About Standards?


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