LISTEN. THINK. SOLVE.

T97 - New ANSI RIA R15.06 & CSA Z434: Robot and Robot System Safety

What is new and different?

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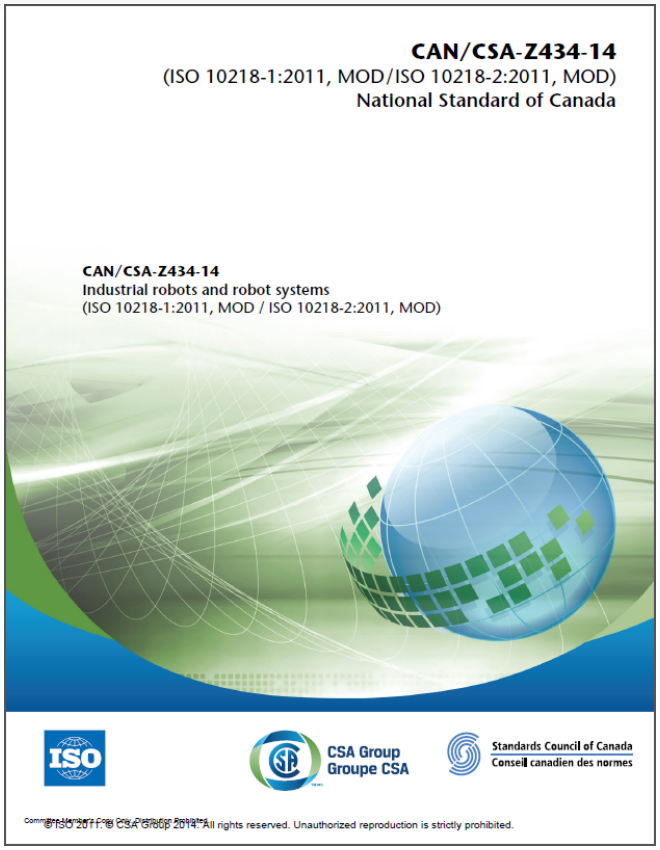
ANSI/RIA R15.06-2012

- Update of ANSI/ RIA R15.06 – 1999!
  - **1999 version was withdrawn at end of December 2014 (as well as TR R15.106 and TR R15.206)**
- National adoption of ISO 10218 -1 & -2
  - ANSI/RIA R15.06-1999 was used as the basis for ISO 10218
- Available from:
  - RIA (hard copy) www.robotics.org *including "old" standards and TRs*
    or
  - ANSI (electronic copy)

CAN/CSA Z434-14



- Update of CAN/CSA Z434 – 03!
  - **2003 version was withdrawn in December 2014**
- National adoption of ISO 10218 -1 & -2
  - Industrial robots and robot systems (Adopted ISO 10218-1, and ISO 10218-2, both with Canadian deviations)
- Available from:
  - CSA (electronic copy) www.shop.csa.ca

    or
  - ANSI (electronic copy)

CAN/CSA Z434-14

Z434-14 includes Canadian deviations (additions) and five additional informative Annexes

- Annex **DVA**
  - Task-based risk assessment methodology
- Annex **DVB**
  - Supplemental Safeguarding Information
- Annex **DVC**
  - Graphical Aides to Understanding Space and Motion
- Annex **DVD**
  - Training
- Annex **DVE**
  - Change management for existing industrial robot applications

International requirements

R15.06 & Z434 are now the "same" as ISO, EN, CA…

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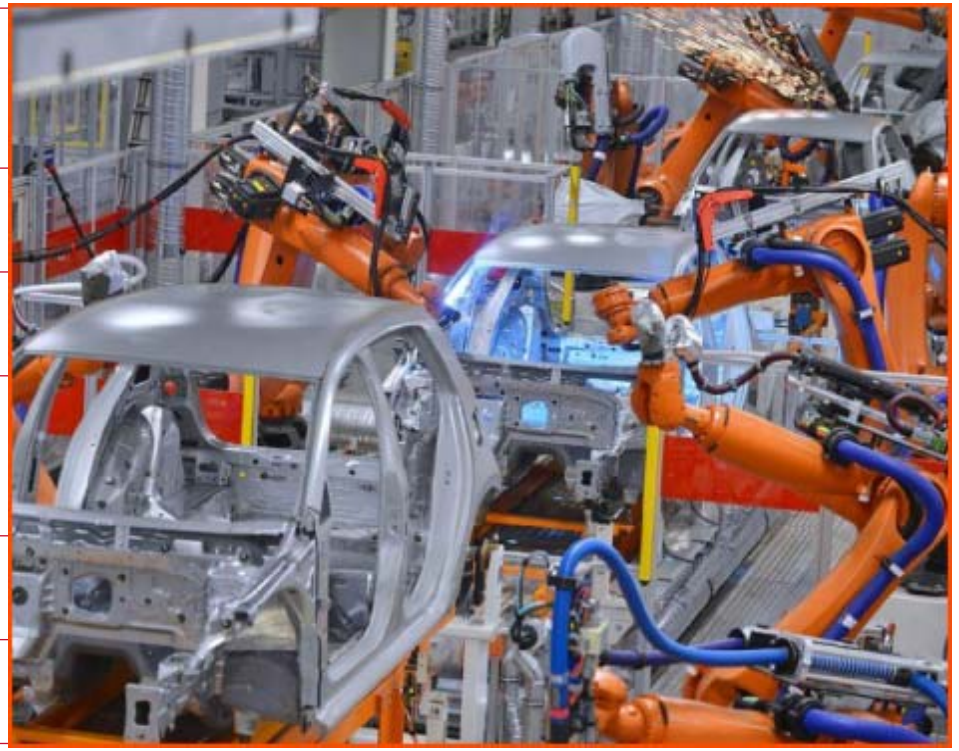
English	Robot
French	Robot or Manipulateur
German	Roboter
Dutch	Robot
Japanese	ロボット *Robotto*
Greek	ρομπότ
Spanish	Robot
Russian	Робот (Robot)



History of ANSI/ RIA R15.06 and CAN/CSA Z434

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	1970	Occupational Health & Safety Act created
	1982	R15.06 drafting started
	1986	Publication of ANSI/RIA R15.06 – 1986
	1986	R15.06 update started
	1992	Publication of ANSI/ RIA R15.06 – 1992
	1994	Publication of CSA Z434-94
	1999	Publication of ANSI/ RIA R15.06 – 1999
	~2000	ISO 10218 started based on ANSI/ RIA R15.06 – 1999
	2003	Publication of CSA Z434-03
	~2004	R15.06 update started (working as a national mirror group to ISO 10218 -1 and -2)
	2006	Publication ISO 10218-1
	2006	ISO 10218 update started
	2007	Publication of ANSI/ RIA ISO 10218-1 – 2007 & TR to use
	2011	Publication of ISO 10218-1 and ISO 10218-2: 2011
	2012	ANSI/ RIA R15.06 adopts ISO 10218-1 and -2:2011
	2014	Publication of CSA Z434-14

ANSI Top Seller

1961

2014

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All that is new with R15.06-2012 and Z434-14?

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- Standard structure
  - Part 1: robot (that which comes from robot manufacturers)
  - Part 2: integration: requirements placed on the integrator
    (can also be the User when the User is acting as the integrator)
- Terminology changes
- Normative references to ISO (for safeguarding, see TR R15.406)
- Risk assessment REQUIRED
- Collaborative robot operation (the issue is the application – not just the robot)
  - *This topic is GREATLY misunderstood!*
- Min / Max changes to perimeter guard dimensions
- Safety controls circuitry / integration requirements (functional safety)
- Safety features embedded in robot systems (some required or optional)

R15.06 – 2012 and Z434-14: Top changes

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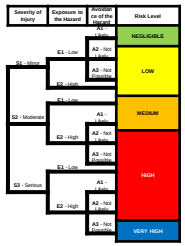
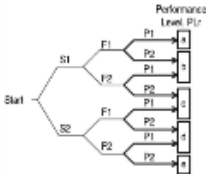
TOP 6

1. Terminology



2. Risk assessment (R15.06 refers to TR 15.306) REQUIRED NOW!

3. Functional safety (that can be quantified)



4. Floor space optimization (due to new features, changes to CLEARANCE requirements, risk assessment, …

5. Collaborative operation (4 types identified)

6. Global acceptance → compliance
References are to ISO & IEC standards

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Terminology changes

New Terms	Explanation
Robot	**Robot arm & robot control** (does **NOT** include end effector)
Robot System	**Robot, end effector and any task equipment**
Robot Cell	**Robot System and safeguarding** (inside the safeguarded space)
Reduced speed	**This was called Slow speed in the 1999 standard**
Protective Stop	**This was called Safety Stop in the 1999 standard** Its purpose is for protection of people. This is different from E-stop.
Manual reduced speed mode	**Often called T1, but also was called Teach Mode in the 1999 standard.** (Teach is a task using manual mode)
Manual high speed mode	**Often called T2, but also called APV in the 1999 standard**
Operator(s)	**All personnel, not simply production operators.** Maintenance, troubleshooting, set-up, production…

Standard “special” words

Shall	**Normative or mandatory requirement**
Should	**Recommendation or good practice**
May	**Permissive or allowed**
Can	**Possible or capable – statement of fact**

All notes are informative and are used to provide additional information or explanation of concepts.

If you see a **“shall”**, **“should”** or **“may”** in a note – the use of the word is an error. Notes are INFORMATIVE!

We try, but we still make mistakes.

R15.06 – 2012 and Z434-14, Part 1

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- Part 1 is for manufacturers, but…
  - Annex D describes OPTIONAL features. Robot manufacturers are NOT required to provide any of these features, however if they are provided, they have to meet the stated requirements in Part 1 (see next slide).
    - Emergency stop output functions
    - Enabling Device features (common enabling device functionality and connecting additional Enabling Devices)
    - Mode section (providing mode information as a safety related functions)
    - Anti-collision sensing awareness signal (not safety-related function but helpful)
    - Maintaining path accuracy across all speeds, so that using T2 is not needed
    - Safety-rated soft axis and space limiting (allows smaller cell footprints)
      Ex: FANUC DCS, Kuka Safe Operation, ABB SafeMove, Yaskawa FSU…
    - Stopping performance measurement
  - **Do NOT presume that these features are provided. OPTIONS!**

OPTIONAL safety-related robot features

See also Part 1, Annex D

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- 5.5.3 **Protective stop when power is retained**
  (Stop Cat 2 – not functional safety structure category)
  - "**May**" be implemented as Stop Cat 2…
    Stop robot motion, remove/control power to robot motors, other hazards controlled by robot, monitored standstill function
- 5.6.3 Safety-rated reduced speed control (≤ 250 mm/sec)
- 5.6.4 Safety-rated monitored speed (of an axis or TCP)
- 5.10.2 Collaborative Safety-rated monitored stop
- 5.10.3 Collaborative hand guiding with safety-rated monitored speed
- 5.10.4 Collaborative power & force limiting by inherent design or control – what does this mean?
- 5.12.3 Safety-rated soft axis and space limiting

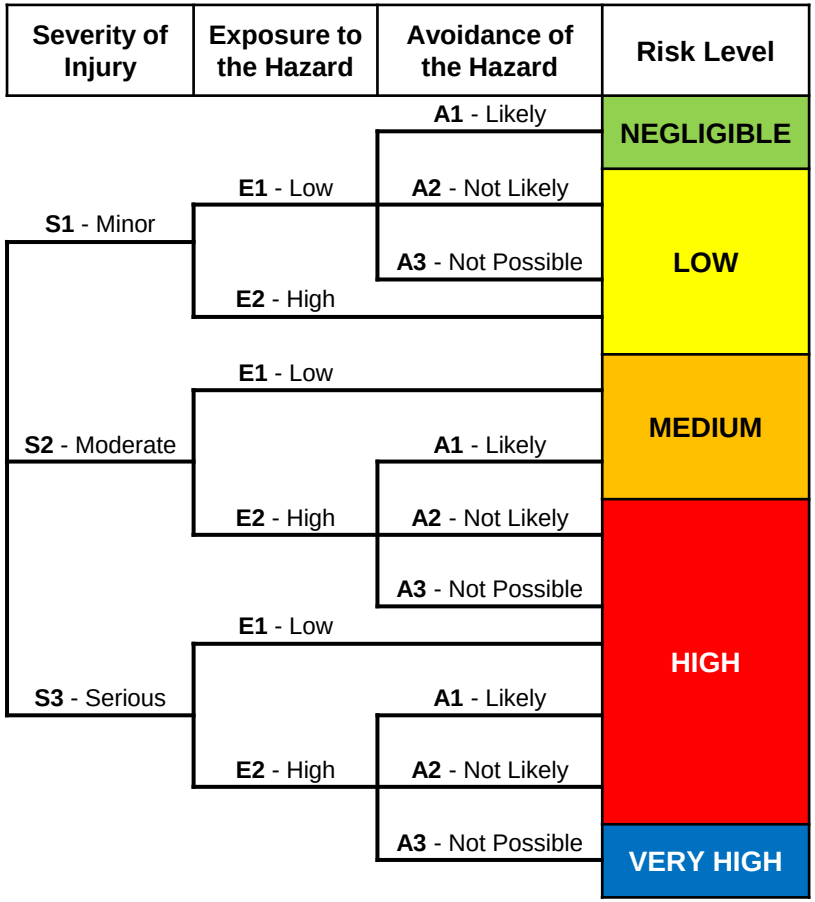
Impact to Integrators & Users

- **Part 2 (ISO 10218-2 = R15.06 & Z434 Part 2) Robot systems & Integration**
  - This is the BIGGY for Integrators (and Users to know)
- **Users are not specifically addressed in ISO 10218-2**
  - CSA Z434-14 includes deviations for User requirements.
  - If a user acts as an integrator, then integrator requirements apply to the user.
  - Users need to use the information provided by the integrator.
  - They need to address residual risks, typically develop procedures & training, train personnel, adding any warnings / signs and safety management.
- **Integrators/ Users: optional features in Part 1, Annex D needed?**
  - **Know before buying robots**. A robot that meets ISO 10218-1 (which is R15.06 and Z434 Part 1), only has these optional features if you request them or if the manufacturer states that their robot has these options as “standard”.
  - Then **START READING the standard**!
  - **Validation & Verification, Clause 6, REQUIRES Annex G** (p 127 Part 2).

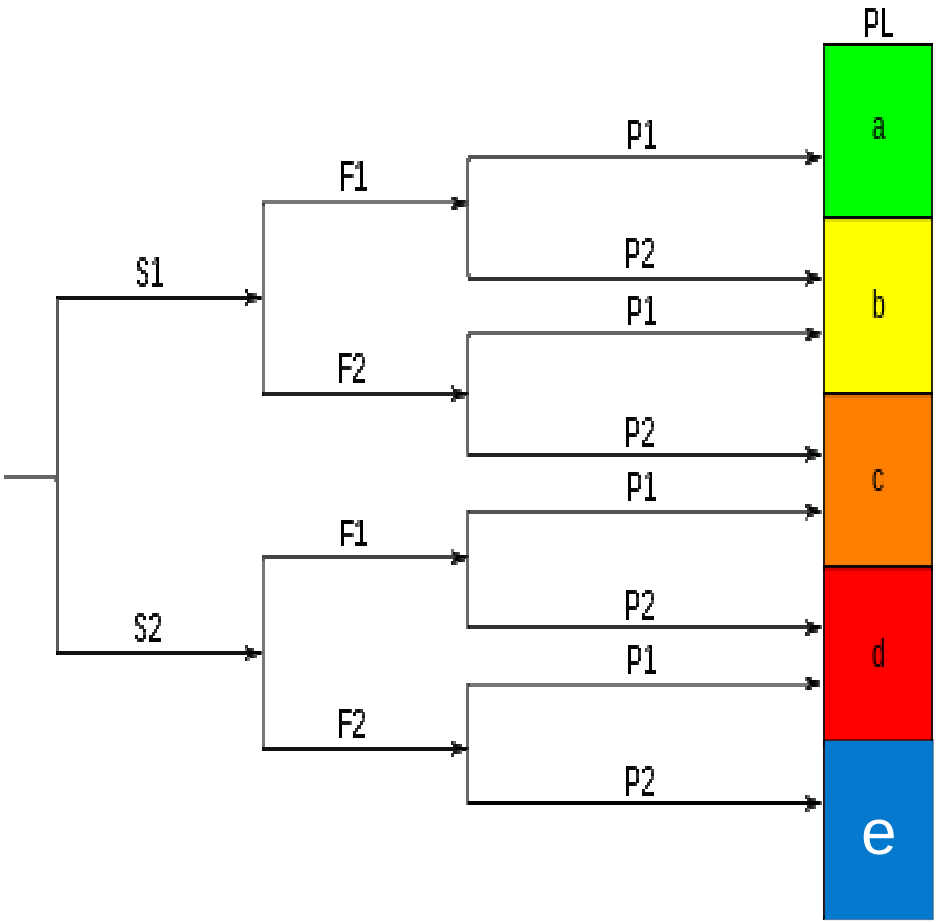
R15.06: 2012 and Z434-14 – Part 2

- **Clause 1:** Scope
- **Clause 2:** Normative References
  - ISO to be used for global (including US) compliance while some ANSI standards can be used instead of ISO if compliance is for US only
- **Clause 3:** Terms and definitions
- **Clause 4:** Hazard Identification & Risk Assessment
  - (R15.06 see TR R15.306, Z434 see Annex DVA)
- **Clause 5:** Safety Requirements and protective measures
  - 5.2: Functional safety (ISO 13849-1 & IEC 62061) requirements and equivalency to "Control Reliability"
  - 5.10: Safeguarding (R15.06 see TR R15.406, Z434 see Annex DVB)
- **Clause 6:** Verification & validation of safety requirements and protective measures (w/NORMATIVE reference to ANNEX G, Part 2)
- **Clause 7:** Information for Use (page 101, Part 2)

Linkage of Risk Assessment to Functional Safety



TR R15.306 Table 2



ISO 13849-1 Risk Graph

Part 2: 5.2 Functional safety

- ISO 13849-1:2006 and IEC 62061 provide performance metrics for Functional Safety
  - Can quantify performance, determine requirements, and validate compliance
- “Control Reliable”: concept in 1999 standard
  - PL=d with structure category 3 is equivalent to the requirements in the 1999 for “control reliability” :
    - A single fault does not lead to the loss of the safety function;
    - The fault shall be detected before the next safety function demand;
    - When the fault occurs, the safety function is performed and a safe state shall be maintained until the detected fault is corrected;
    - Reasonably foreseeable faults shall be detected.

RIA TR R15.306 – 2014
Table 5 – Min functional safety requirements to risk

Risk Level	Minimum SRP/CS requirements	
	PL_r	Structure Category
NEGLIGIBLE (see 5.6.1)	c	1
LOW	c	2
MEDIUM	d	2
HIGH	d	3
VERY HIGH (see 5.6.2)	e	4

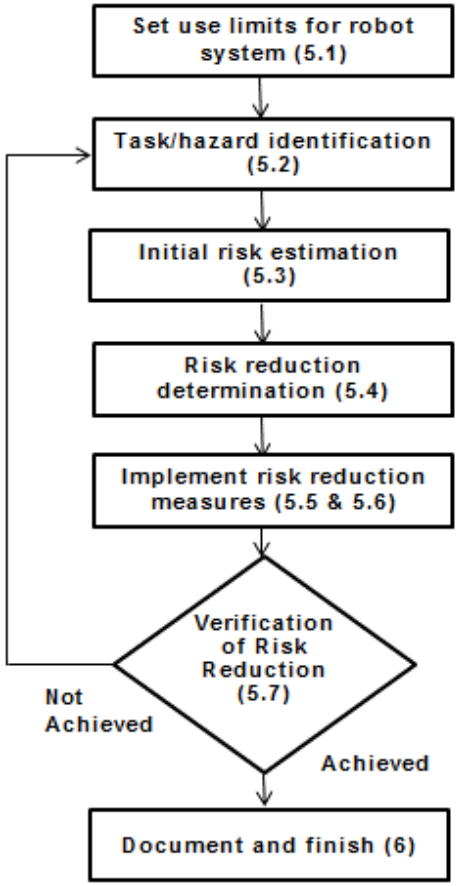
Robot safety standards (ANSI, CSA, ISO, EN) require PLd, Cat 3 unless a risk assessment determines another PL and Cat would be appropriate. A higher requirement is not expected due to hazards associated with a robot system. PLd, Cat 3 is equivalent to Control Reliable!

NOTE – Applications with risk levels deemed "VERY HIGH" are likely to have hazards addressed in other specific safety standards, for example hazardous locations, hand fed presses.

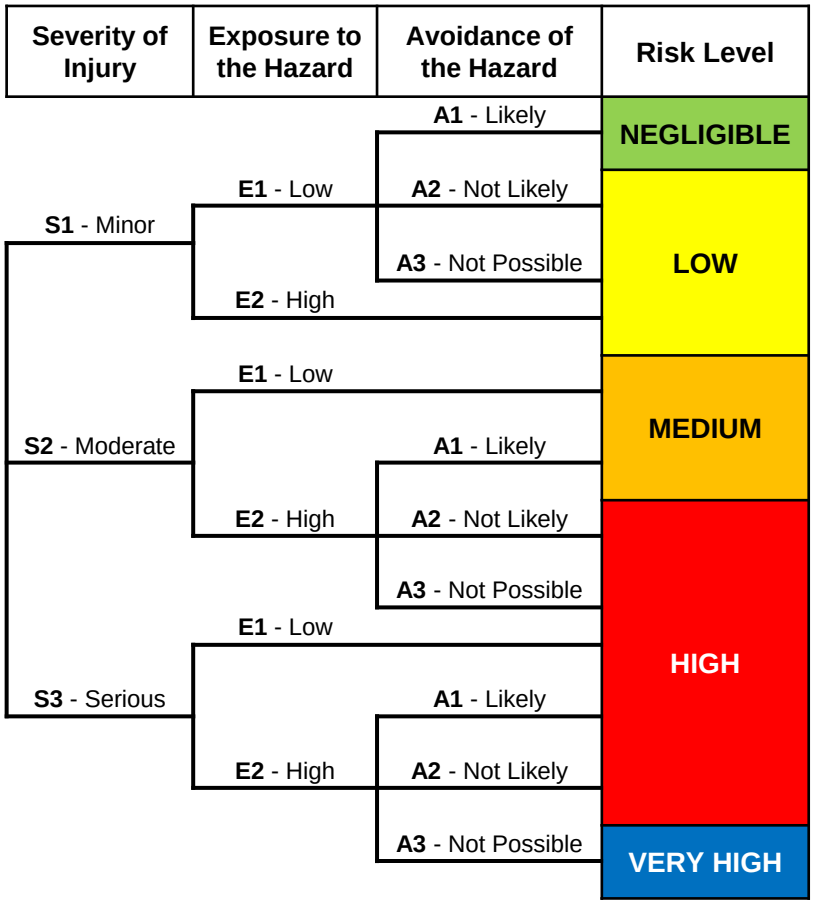
Optimize your Floor Space (1)
Risk assessment: task locations & access

- 1. Conduct a risk assessment (required in 2012, optional in 1999) to identify tasks & hazards & protective measures associated for all phases of operation – including the need for access for tasks and providing space (including clearance) as needed.

Typical flow chart



RIA TR R15.306
(modification of ISO 13849-1:2006 Risk Graph)



Optimize Your Floor Space (2)
Robot control use for the restricted space

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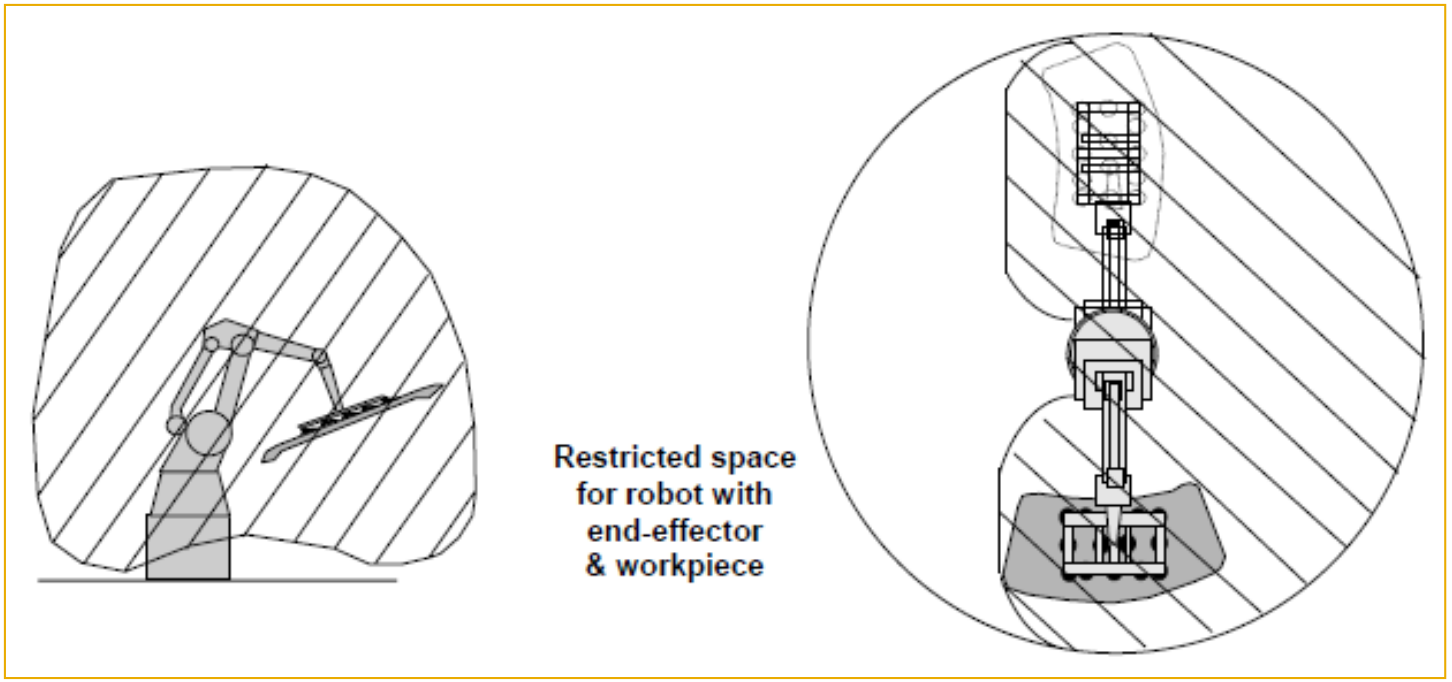
- Use safety-rated soft axis and space limiting to result in a restricted space that is smaller than what could have been done previously.
- "Limiting Devices" (safety functions) reduce the "maximum space" to the restricted space. See Part 1, 5.12.3 and Part 1, Annex D
  - Maximum, Restricted, and Operating Spaces include the robot, end-effector, & part.



Optimize Your Floor Space (3)
Clearance: when and what is required…

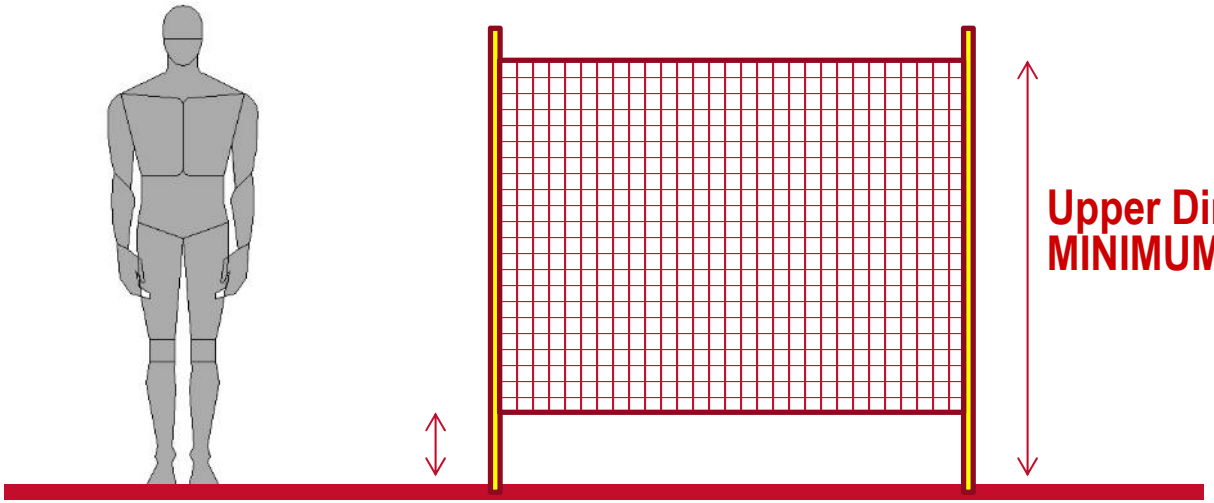
- Apply safeguarding and **IF ONLY Manual Reduced Speed (T1 & no T2),** then clearance needed for **tasks inside the safeguarded space where there is a hazard due to lack of space (pinch, crush, trapping)**. See Risk Assessment mentioned in (1).
  - No task→ no need for clearance! **Be real** in the risk assessment.
  - If there is a task with a space issue, then provide space based on the body part that is exposed. For trapping (body/ chest), 20 in needed. If another body part, then use ISO 13854 for dimensions to prevent crushing.
    - 1999: 18-inch clearance from the operating space was required. Now the restricted space is considered to be the hazardous area – however standard is silent on this.
  - Case studies have shown up to a 30-40% reduction in footprint!

Photo courtesy Assa Abloy

Important: If high-speed manual T2 is available, then 20-inch clearance is required regardless of the risk assessment (Part 2, 5.5.2)

Perimeter Guard Dimension Comparison

	R15.06-1999	ISO 10218 & R15.06-2012	CSA Z434
Lower Dimension	12 in.	7 in.	6 in.
Upper Dimension	60 in.	55 in.	72 in.



Only if hazards cannot be accessed by reach over, under and through.
Example, if there is a hazard within 43" of the bottom, then the guard must have a lower dimension smaller than 7". (see ISO 13855 or RIA TR15.406)

Collaborative Operation

- **Four types of collaborative operation (Part 1, 5.10; Part 2, 5.11) for collaborative applications (can be a mix of the following) – all while in AUTOMATIC OPERATION:**
  1. **Safety-rated monitored stop**
     - Operator may interact with robot when it is stopped
       Automatic operation resume when the human leaves the collaborative workspace
  2. **Hand-guiding operation**
     - Operator in direct contact with the robot, using hand controls
  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
  4. **Power and force limiting**
     - Incidental contact between robot and person will not result in harm to person.
       Reference ISO TS 15066. This requires a detailed risk assessment that includes each body region. **FOR APPLICATIONS WHERE AT WORSE CASE, ONLY SLIGHT INJURY!**
- **A collaborative application could include one or more of the above.**

Additional guidance for collaborative operations is being drafted (ISO TS 15066). Mostly about Power & Force Limited and Speed & Separation Monitoring.

Collaborative Terminology

- Collaborative… Part 1, 5.10 & Part 2, 5.11
  - Collaborative Robot, Definition: Part 1, 3.4 & Part 2, 3.2
    - robot designed for **direct interaction with a human** within a defined collaborative workspace (3.3)
  - Collaborative Workspace, Definition: Part 1, 3.5 & Part 2, 3.3
    - workspace within the safeguarded space where the robot <system> and a human can perform tasks simultaneously during production operation
  - Unintended consequence about title "Collaborative Robot"
- Safeguarding of a collaborative application is determined by the risk assessment! *Power and force limited robot used to pack knives?*

NOTE: It is an OPTION for robots to be equipped for the POTENTIAL of use in collaborative applications.

With R15.06 – 2012 and Z434-14: Global design

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Global harmonization = savings through the whole supply chain:

- Robot **manufacturers** can use a single robot design.
- Robot **integrators** design a single robot cell that can be installed anywhere.
- **Users** can have a single solution that can be easily moved between countries.

Canada (CSA Z434-14 released November 2014)

- Adoption of ISO 10218 w/ national exceptions
  - Limits on collaborative operations
  - Slightly different fixed perimeter guard dimensions (6” & 72”)
  - Additional informative Annexes (essentially TR R15.0306 and some from “old” CSA Z434)

ANSI RIA - What's Next?

- RIA Technical Reports just released!
  - RIA TR R15.306, Task-Based Risk Assessment
    - Updates guidance in ANSI/RIA R15.06-1999, Clause 9
  - RIA TR R15.406, Safeguarding
    - Updates guidance in ANSI/RIA R15.06-1999, Clauses 10 and 11
    - Provides international standards compliance information.
      - If further details are needed, look at the ISO standards.
  - RIA TR R15.506, Existing Systems
    - Provides guidance as to when the guidance outlined in ANSI/RIA R15.06-2012 would apply for robot cells built to ANSI/RIA R15.06-1999 requirements (or earlier).

Challenges moving ahead…

- **Change is difficult.** We have a new standard (and TRs) to learn.
- **Risk assessment is required**. Some people are not yet comfortable with risk assessment. But some have become quite comfortable.
  - Drive for new TR15.306 to have 3 levels of severity.
- **ISO 13849-1 and IEC 62061 are relatively new to the US**.
  - Functional safety can seem scary because it includes equations.
    - Math can be easily done by free software (SISTEMA for ISO 13849-1).
    - Combines reliability with diagnostics coverage (to detect a failure), rather than simply relying on an architecture (categories).
  - Functional safety really requires understanding the components (machine and safety-related), THEN integrating them properly. (More expected now than previously expected… progress)
- **We now have PLe which did not exist in EN954.**
  - Many people are **mistakenly** getting to PLe as a requirement of their risk assessment. See RIA TR R15.306 Tables 2 and 5.

Preview of TR15.306…

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Risk assessment,
Food for thought…

Part 2: Clause 4 Hazard ID & Risk Assessment

RIA TR R15.306 Tables 2 and 5

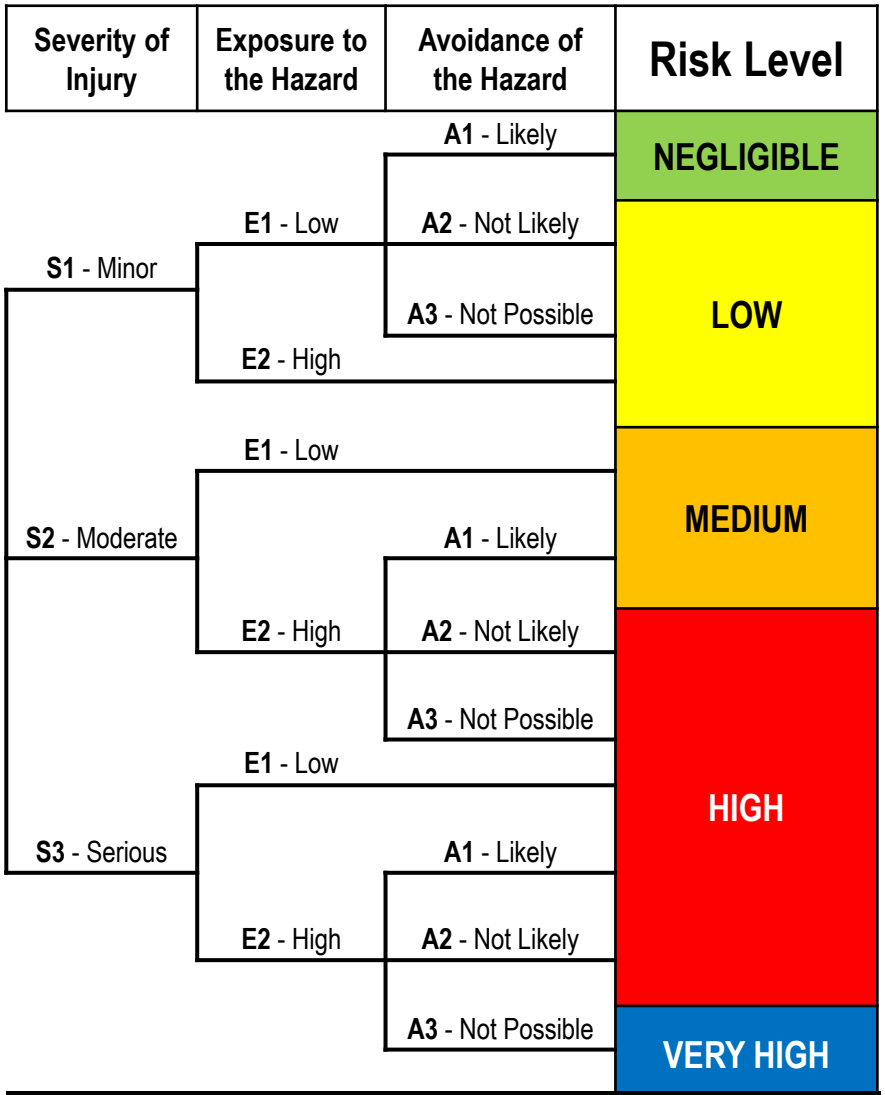

Table 2 – TR 15.306

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LOW	c	2
MEDIUM	d	2
HIGH	d	3
VERY HIGH (see 5.6.2)	e	4

Table 5 – TR 15.306

RIA R15.06 – 1999

Risk Assessment

Severity	Exposure	Avoidability	Risk Reduction Index
S1 Slight	E1	A1	R4
		A2	R3B
	E2	A1	R3A
		A2	R2C
S2 Serious	E1	A1	R2B
		A2	R2B (R15.06) R2A (CSA Z434:03)
	E2	A1	R2A
		A2	R1

Functional Safety of SRP/CS

Circuitry Description (*if risk reduction includes a control system*)	Min Equivalency to EN 954 per R15.206
Simple	B
Simple	B
Single Channel	1
Single Channel	1
Single CH w/monitoring	2
Single CH w/mon (R15.06) Control Reliable (CSA)	2 (R15.06) 3 (Z434-03)
Control Reliable *NOTE: Control Reliable is equivalent to Cat 3 (PLd)*	3

Very high never previously addressed! →

RIA TR R15.306 – 2014

Risk Assessment

Severity	Exposure	Avoidability	Risk Level
S1 Minor	E1	A1	Negligible
		A2	Low
		A3	
	E2	A1	
		A2	
S2 Moderate	E1	A1	Medium
		A2	
	E2	A1	High
		A2	
		A3	
S3 Serious	E1	A1	
	E2	A2	
		A3	Very High

Functional Safety SRP/CS

ISO 13849-1 PLr	ISO 13849-1 Structure Cat	IEC 62061 (SIL)
c	1	SIL 1
c	2	SIL 1
d	2	SIL 1 or SIL 2
d	3	SIL 2 Hardware Fault Tolerance: 1 Mission Life: 20 years
e	4	SIL 3

What's Next?

- Collaborative Operations / Applications (ISO TS 15066)
  - Planned release: 2015
- Manual load station (ISO Technical Specification S)
- New Projects
  - Robot / AGV combination
  - Modularity
  - Vocabulary
- OTHER…

How do we write a safety standard for this?

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Questions?

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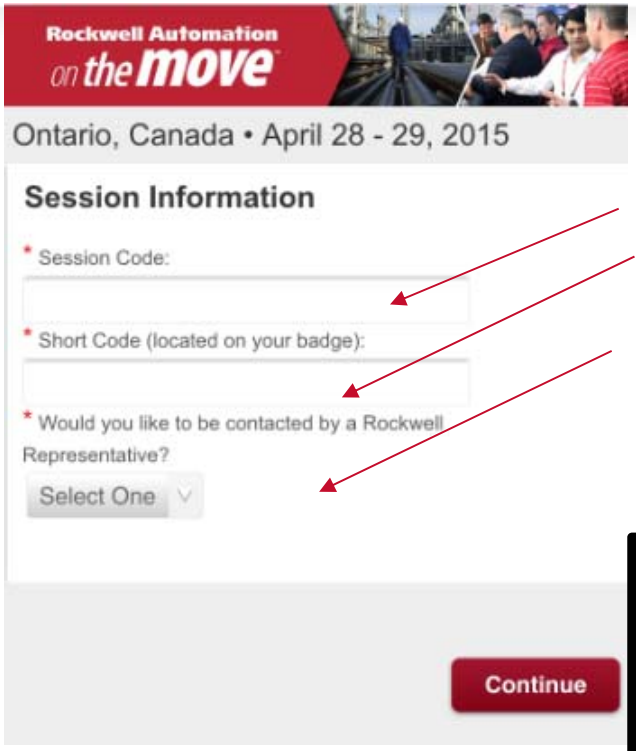

Then fill in the required information on the survey screen:

1. Your Session Code (i.e. T200)
2. Your Short Code Located on your Badge
3. Select "YES"
4. Hit "Continue"