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Introduction to Industrial Mobile Robot Safety: R15.08

Jeff Pratt

Interim Chair of R15.08

Senior Corporate Environmental, Safety, and Health Engineer

Crown Equipment Corporation

IRSC 2022: It's great to be back!

The last in-person IRSC was in Indianapolis on Oct. 15-17 in 2019

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During the pandemic, we were more comfortable working with robots than with each other!

https://www.automate.org/industry-insights/reducing-covid-risks-with-robots

Welcome

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Pratt '23
Jeff Pratt
UNIVERSITY of SAINT FRANCIS


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Not in scope of R15.08

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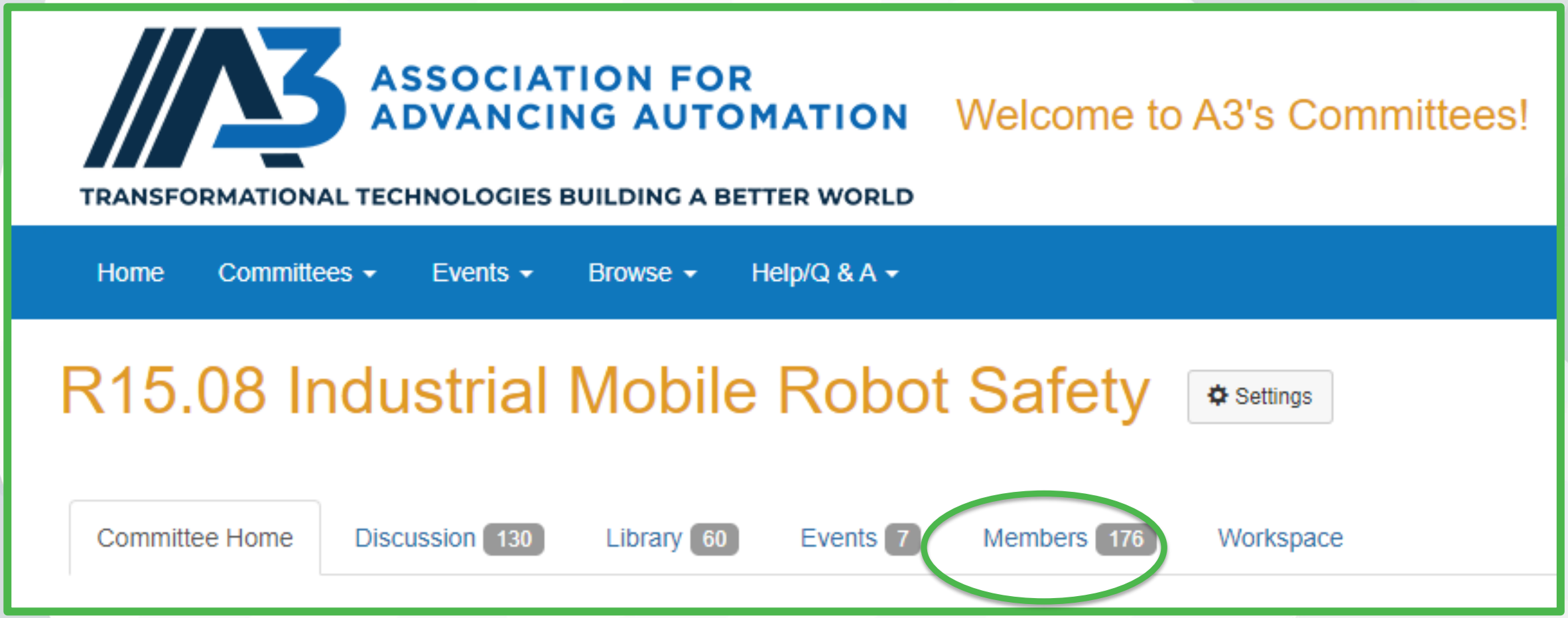
T 1000 Series

DualMode R
R 1000 Series

R15.08 is an International Effort



R15.08 Committee @ Fed Ex Institute of Technology

THE UNIVERSITY OF MEMPHIS

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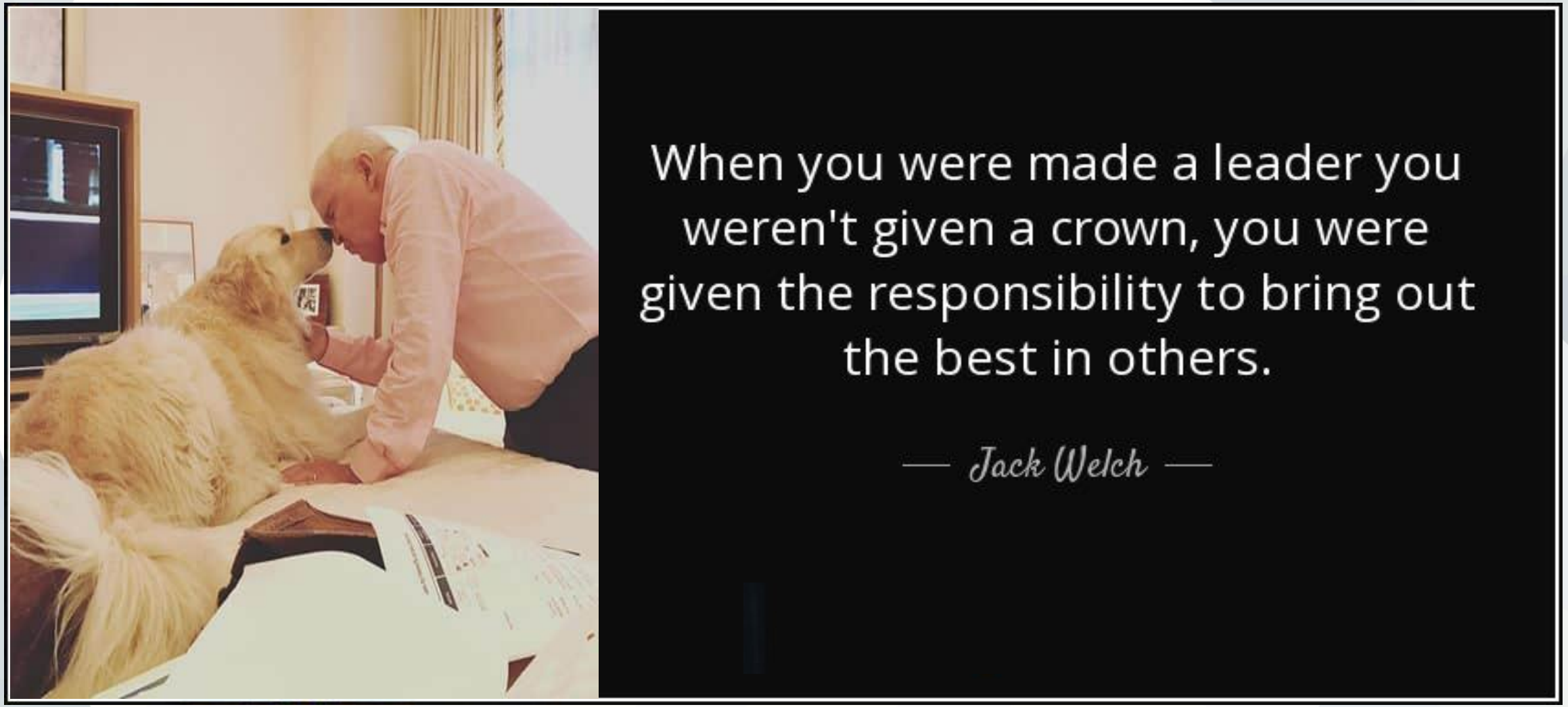
R15.08 Interim Chair–



https://www.linkedin.com/pulse/jack-welch-culture-leadership-dwight-pond

Industrial Mobile Robots – Today's topics

- Evolution of Industrial Robot Safety
- A3's Robot Standards
- Introduction to Mobile Robots
- R15.08 – Information for Use
  - Group Participation: How Mobile Risk Assessments

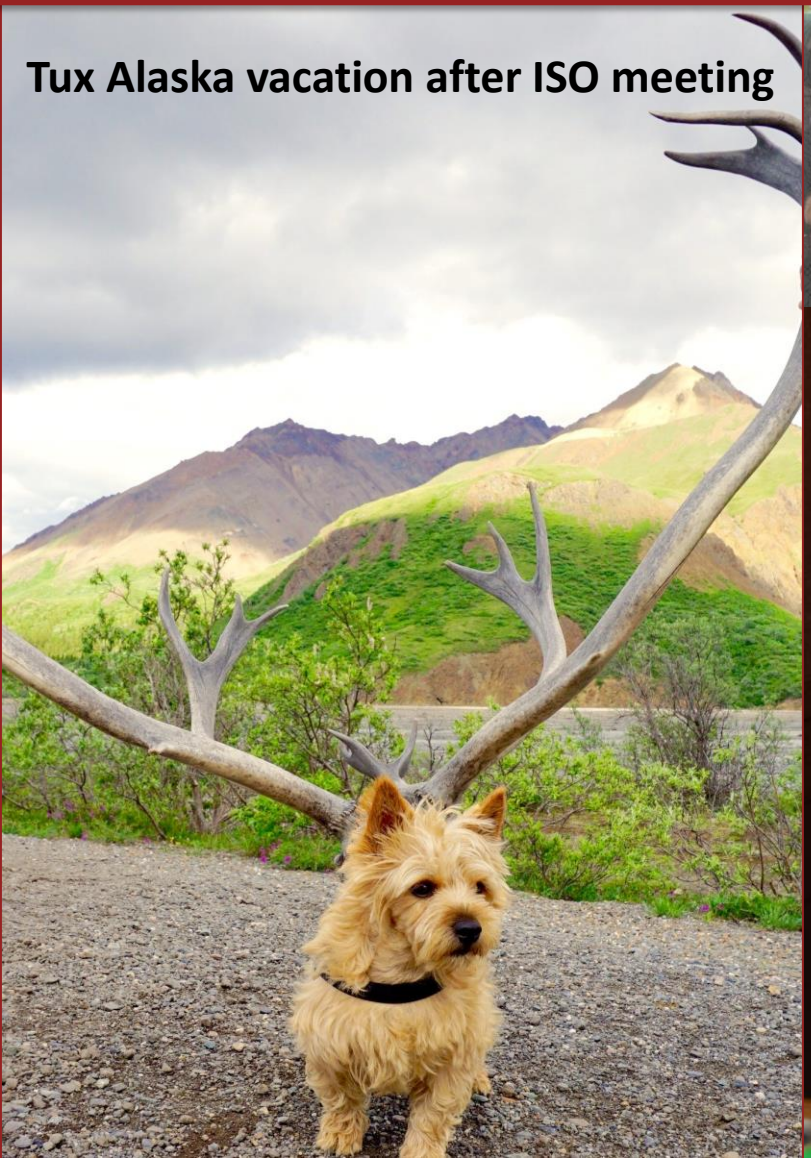
Evolution of Industrial Robot Safety

- **1980's:** Long-standing practice for industrial robot safety: Keep people safe by keeping them physically separated from the industrial robots.
  - Industrial robot arms/non-collaborative – heavy-duty.
  - Fenced-in-place.
  - Still the majority of robot systems sold today.

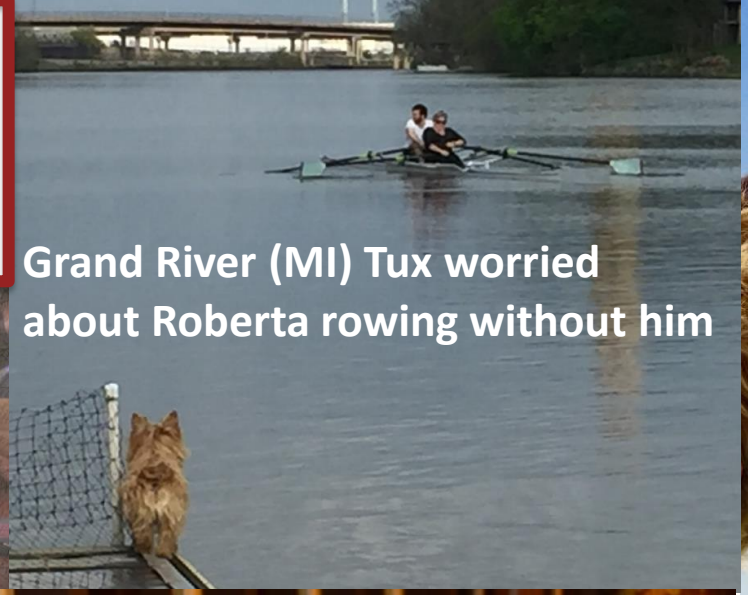
- **2010's:** Advancements occurred in Collaborative robot systems.
  - Industrial robot arms (manipulators) – that are collaborative-ready
  - Still fixed-in-place – but might not need a fence?

- **Today:** Advancements in "Mobile" robot systems.

People love Dogs

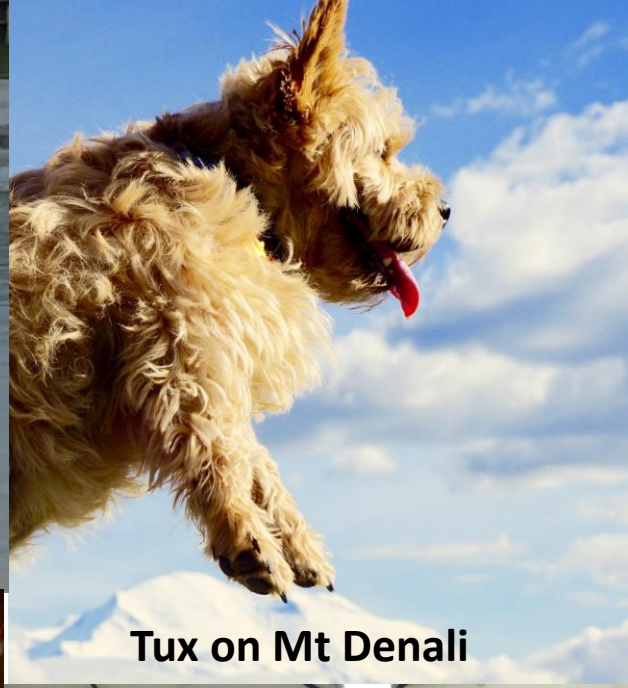


Tux Alaska vacation after ISO meeting



Grand River (MI) Tux worried about Roberta rowing without him

Tux Florida for ISO meeting



Tux on Mt Denali

Tux in Italy for ISO meeting.

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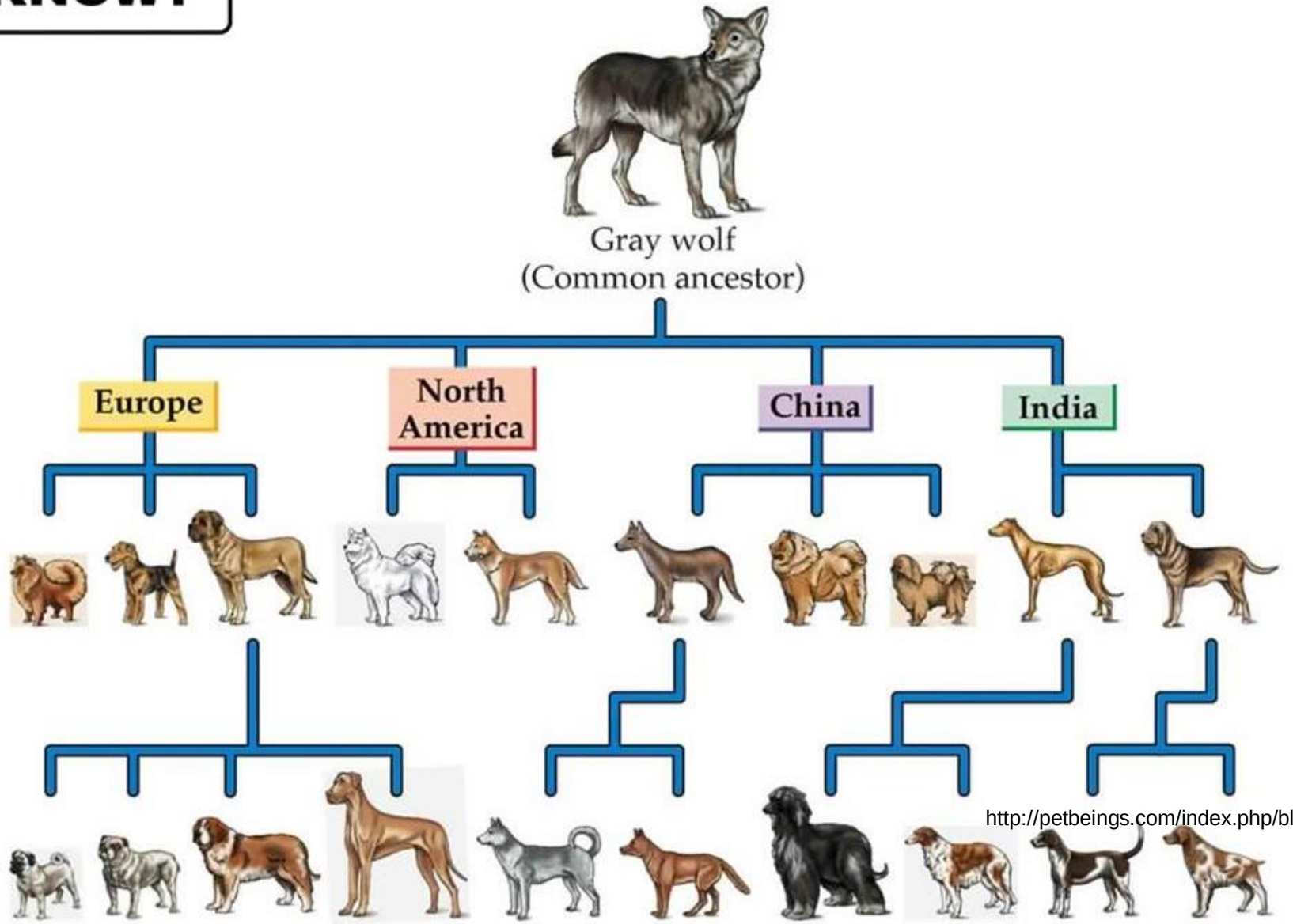
DID YOU KNOW?

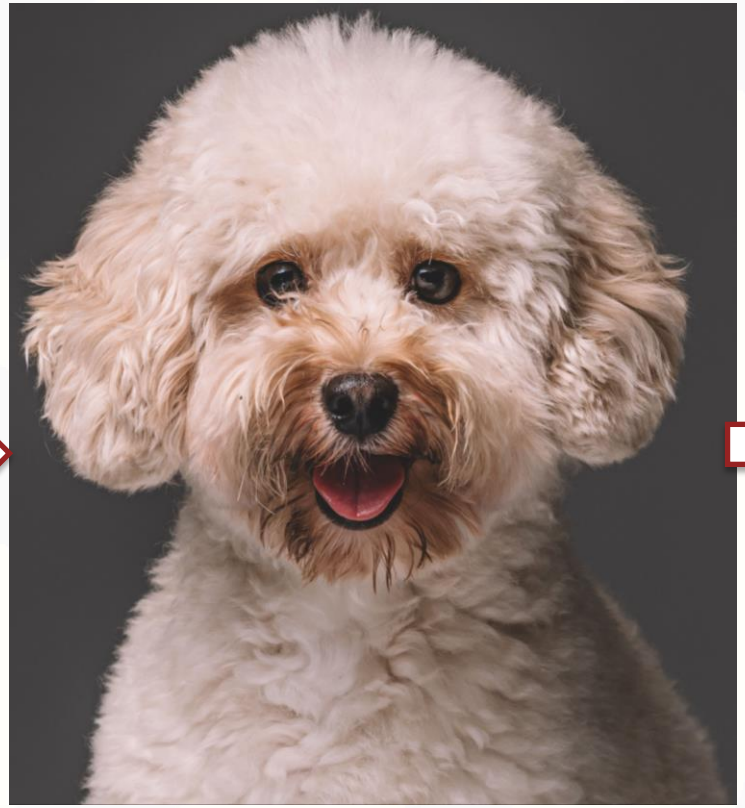
All Dogs evolved from Wolves



http://petbeings.com/index.php/blog/blogdetails/24/Evolution-of-WOLF-into-DOGS

DID YOU KNOW?

All dogs evolved from Wolves



“Big Bad Wolf”

“Poodle”

“Border Collie”

Robot Evolution

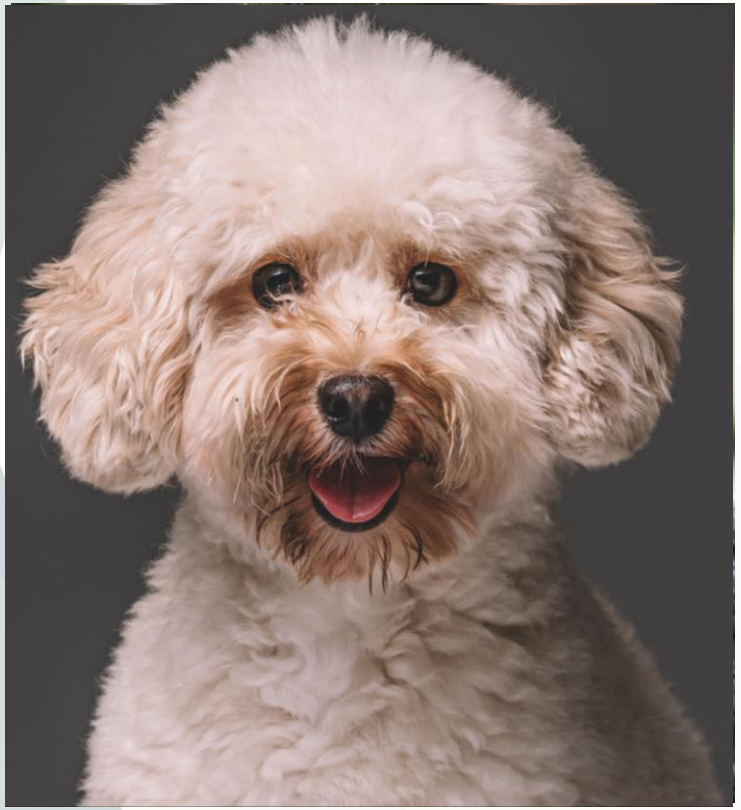
Industrial

"Big Bad Wolf"

- "The" *Original*.
- Very Strong, Wild/More difficult to Train.
- Cavemen: They can help mankind but need to be domesticated.

Robot Evolution

Collaborative



“Poodle”

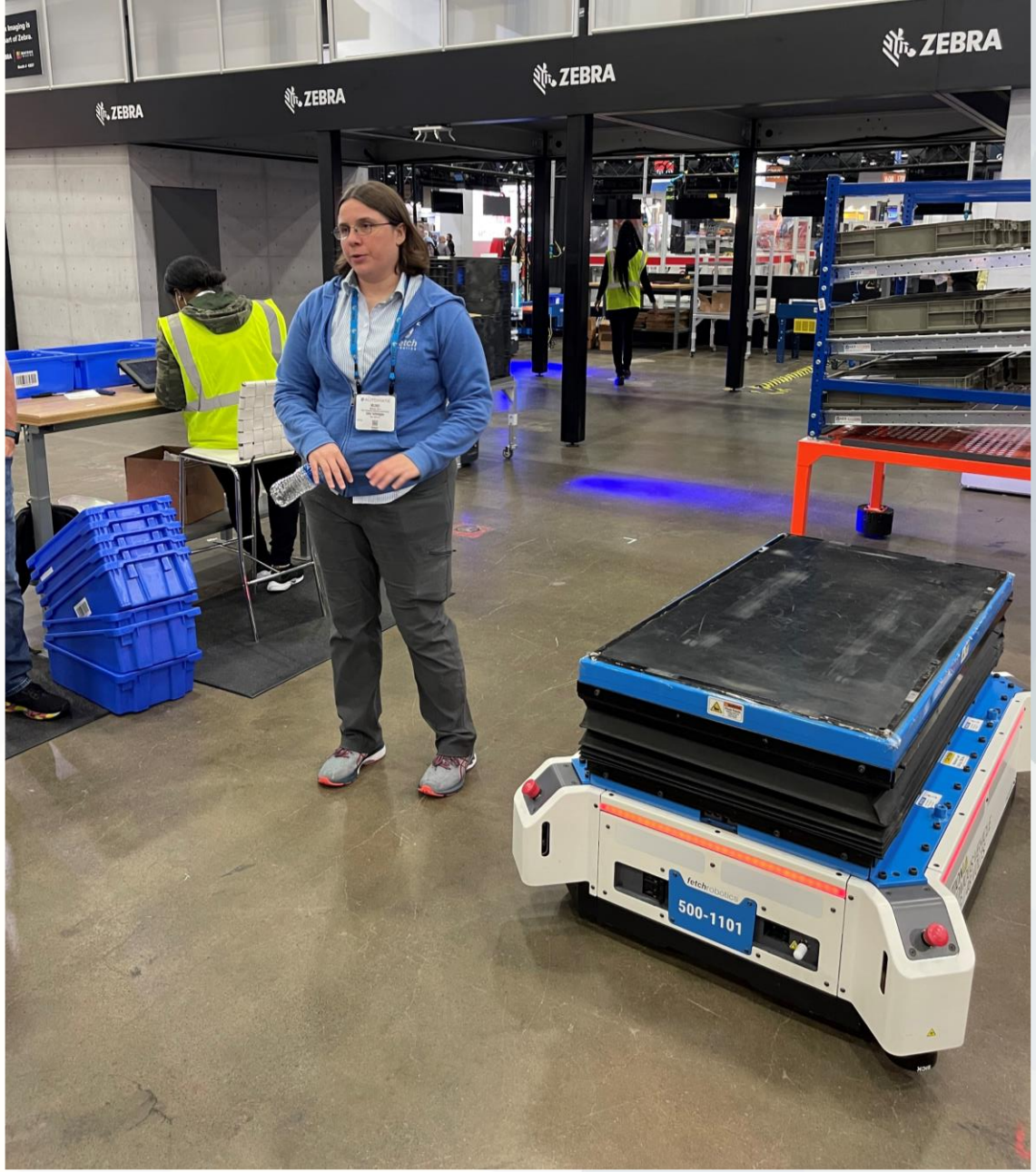
- Very smart, and easily trained.
- Marketed as… a lap dog that you can work closely with!
- Not as powerful as a wolf but we know its end effectors (teeth & nails) can still cause harm especially to the head/face, and neck.

Robot Evolution

Mobile

“Border Collie”

- Highly intelligent & highly trainable.
- Border Collies excel in many roles, but being your companion is their greatest!
- The Border Collie is the class valedictorian of canines. They’re energetic workaholics who love having a job to do **including playing Fetch**.



Zebra Technologies Has Acquired Fetch Robotics

Where People and Robots Work in Harmony for the On-Demand Economy

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Keep Separated?

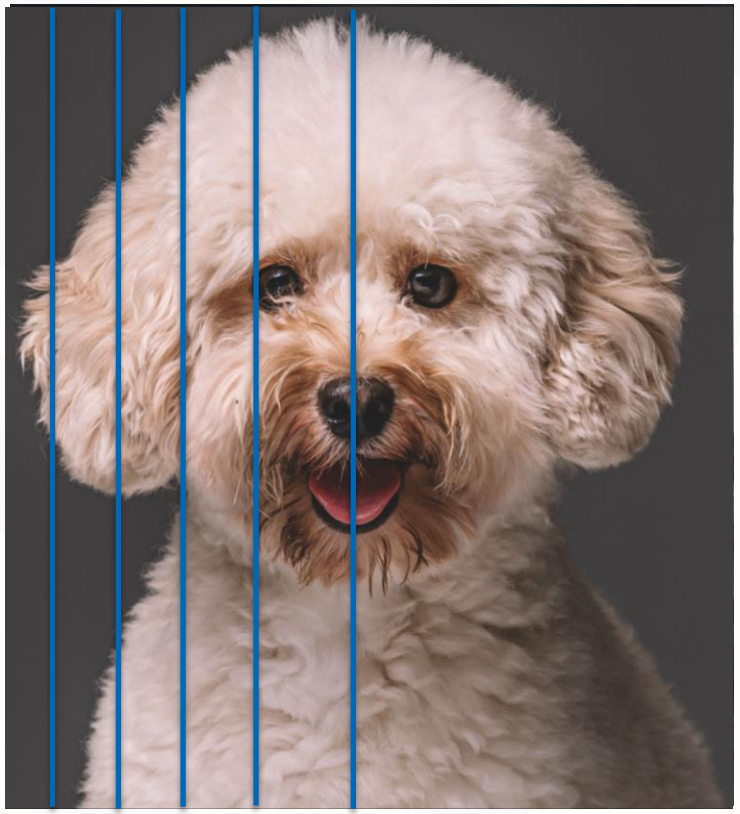
Technology evolves at such a higher rate than natural evolution so where is the guarding line drawn?

Robot Evolution: Guarding

“Big Bad Wolf”

Industrial

“Poodle”

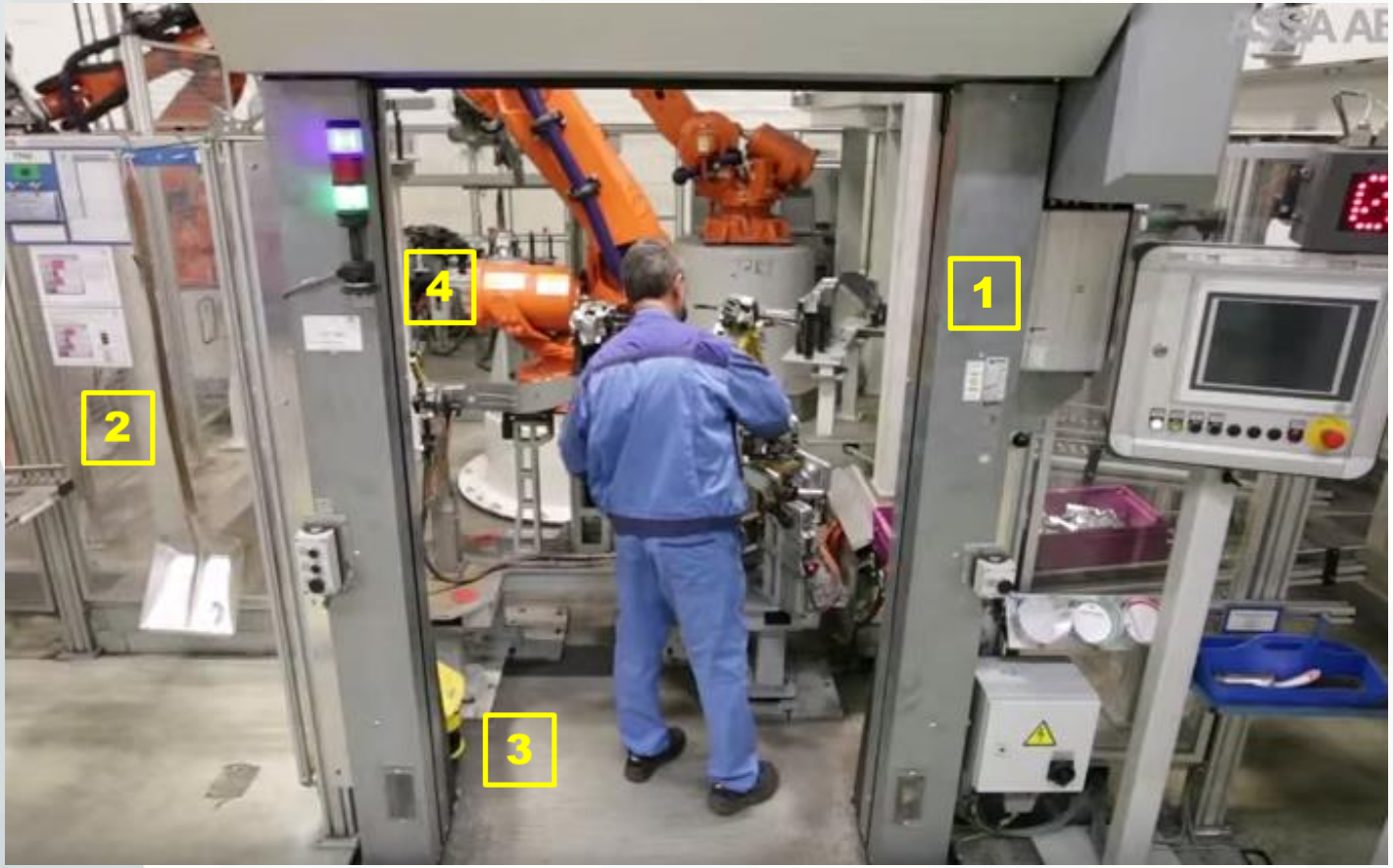


Collaborative

“Border Collie”

Mobile

Industrial Robots: The Wolf. Keep Separated



Examples: Safeguarding

1. Safety door (interlocked moving guard)
2. Fixed guards
3. Safety scanner
4. Robot axis limits

Evolution #1: Collaborative Robots (Poodle)

- About 10 years ago
  - Industrial robot arms (manipulators) – **collaborative-ready**
  - Still fixed-in-place (or defined-motion) – but might **not*** need a fence?
    - *** Only if** integrated into an appropriately collaborative robot system!
- 4 types of collaborative operation
  - Power and force limited (PFL)
    - Smaller, lighter-duty, limited in the forces they can exert
    - Typically also possess "inherently safe" design factors – compliant materials, rounded edges, etc.
  - Safety-rated monitored Stop
  - Speed & separation monitoring (SSM)
  - Hand-guided (HG)

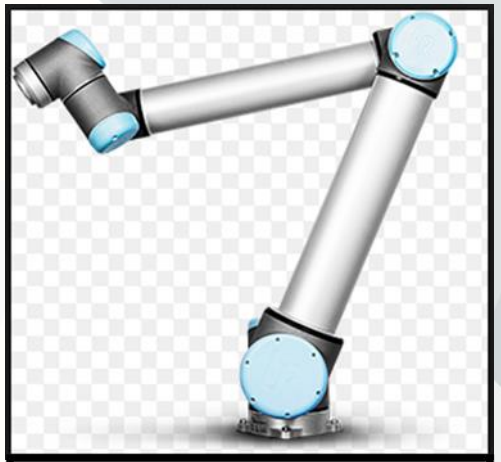
Can be done with conventional (non-PFL) industrial manipulators!

Evolution #1: Collaborative

Hand-guiding (HG)

Speed & separation monitoring (SSM)

Power & force limiting (PFL)



Evolution #2: Mobile Robot Systems (Border Collie).

Then

- For fixed-in-place robot systems, Whether convention or collaborative, the origin is a "robot cell"
- For fixed-in-place: Worker must approach the hazard in order to be exposed to it.
    - Usually with some intention to interact with the robot system
    - Can be trained in safe practices for interaction

NOW: For mobile robot systems, the mobile unit can approach workers.

- Mobile robot carries its hazard zone with it
- Worker approached might have no intention of interacting with it, yet still be exposed to the hazard

NOW: Entire facility is the "cell" for mobile robots.

Our Goals

- Keep our “Collies” from running over anyone.
- Provide end-users with the needed information for safe use.

The Mobile Evolution: Growing up with the technology!

Van Wert Robotics team off to World Championships, Houston Texas

https://van-wert-robotics-club.webnode.page/

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A3's Robot Standards: History

Year	Document(s)
1986	ANSI/RIA R15.06-1986
1992	ANSI/RIA R15.06-1992
1999	ANSI/RIA R15.06-1999
~2000	ISO 10218 begun, based on R15.06-1999
2006	ISO 10218-1:2006
2007	ANSI/RIA ISO 10218-1:2007 & RIA TR to enable its use
2011	ISO 10218-1,2:2011

Year	Document(s)
2012	ANSI/RIA R15.06-2012 (U.S. national adoption of ISO 10218-1,2:2011)
2014	RIA TRs 306, 406, 506
2016	ISO/TS15066:2016; RIA TR R15.606-2016 (U.S. nat'l adptn). TR 306 update.
2017	ISO/TR 20218-2:2017
2018	ISO/TR 20218-1:2018. RIA TR R15.806-2018.
2019	RIA TR R15.706-2019.
2020	ANSI/RIA R15.08-1:2020.

A3's Robot Standards: Current Documents

- **ANSI/RIA R15.06-2012 ("R15.06")** > Direct U.S. Adoption of **ISO 10218-1,2:2011 ("10218")**. Safety requirements for industrial robots and robot systems.
- The following Technical Reports for use with R15.06 (10218):
  - RIA TR R15.306-2016. Task-based risk assessment.
  - RIA TR R15.406-2014. Safeguarding.
  - RIA TR R15.506-2014. Applicability for existing systems.
  - RIA TR R15.606-2016 > Direct U.S. Adoption of ISO/TS 15066:2016. Safety requirements for collaborative robots.
  - RIA TR R15.706-2019. User Responsibilities.
  - RIA TR R15.806-2018. Test methods for PFL collaborative robot systems.
- **ANSI/RIA R15.08-1-2020 ("R15.08")**. Safety requirements for Industrial Mobile Robots – Part 1: Requirements for the Industrial Mobile Robot

A3's Robot Standards: Documents Being Updated

Introduction to Industrial Robot Safety ISO 10218, Parts 1 and 2
Todd Dickey, Honda Development and Manufacturing of America, Chair, R15.06 Committee (earlier today).

- **R15.06 > Direct U.S. Adoption of ISO 10218-1,2.**
  - ISO 10218-1,2 is being updated currently; publication is expected in late 2022 to early 2023.
  - U.S. Adoption (new edition of R15.06) will likely be completed and published in the first half of 2023.

A3's Robot Standards: New Projects in Development

- Part 2 of R15.08. Safety Requirements for Industrial Mobile Robot Safety - Part 2: Safety requirements for integration of IMR(s) into an application.
  - In development.
  - Target timing: Complete draft by end of 2022; publication in July 2023.
- Technical Reports Intended for use with R15.06 (ISO 10218-1,2):
  - RIA TR R15.906-202X. Safety-related Software. Nearing ballot/approval.
  - RIA TR R15.1006-202X. Test methods for SSM collaborative robot systems.
  - RIA/ISO/TR 20218-1-2021. Safety Design for End-effectors >> Direct U.S. Adoption of ISO/TR 20218-1:2018. Nearing publication.
  - RIA/ISO/TR 20218-2-2021. Safety Design for Manual Load/ Unload Stations >> Direct U.S. Adoption of ISO/TR 20218-2:2017. Nearing publication.

Introduction to Mobile Robots and Applications

Topics

- What are "Industrial Mobile Robots" (IMRs)?
- How and where IMRs are used?

Evolution #2: Mobile Robot Systems (Spot).

For Mobile, the environment matters.

(This dog theme just isn't going way, is it?)

*Taking care of **D**irty, **D**ull, **D**angerous tasks makes Spot man's best friend. Spot is navigating in Skull Cave. Photos courtesy of Federico Vicentini, Head of Product Safety at Boston Dynamics.*

Stretch

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Stretch

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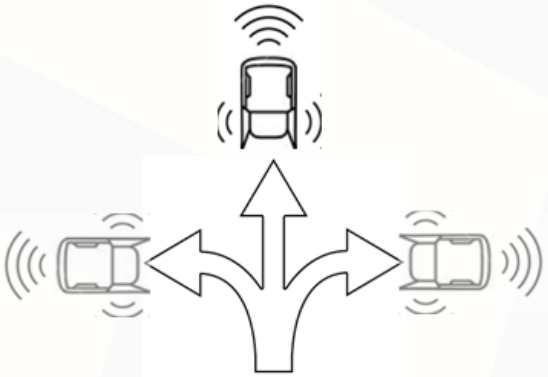
What are the Key Terms?

- Key Terms:
  - Industrial Mobile Robot (IMR)
  - Autonomous Mobile Robot (AMR)
  - Automated Guided Vehicle (AGV)
  - Mobile Manipulator
  - Industrial environment

AMRs vs AGV

- AMRs plot their own course autonomously
- AGVs typically follow a planned route
- AMRs are typically smaller than AGVs



But the lines are blurring!

What are IMRs?

- Distinction between AMR and AGV
  - Fixed path of AGV vs free-space navigation by AMRs
  - “Typically…” AGV must stay on its path; if encounters obstacle, stops.
  - There is a gray area; ongoing discussions
- Type ABC definitions
  - **IMR Type A** – Industrial Autonomous Mobile Robot (AMR) – only capabilities are locomotion and autonomous navigation
  - **IMR Type B** – AMR with Attachment (not a robot arm); any other capability beyond mobility
  - **IMR Type C** – “Mobile Manipulator”: Mobile platform (AMR or AGV) with manipulator (robot arm) as the Attachment

What are IMRs?

- Benefits of IMRs: Flexibility, nimbleness, size
- Is an IMR an AMR or an AGV?
  - **Yes… sort of**
  - An AMR in an industrial environment = YES
  - An AGV in an industrial environment = Yes, **IF** has an industrial robot manipulator as an attachment (NOT in other configurations).

R15.08- Part 1 Manufacturer Requirements

- What are "Industrial Mobile Robots" (IMRs)?
- How and where IMRs are used
- Key requirements in R15.08-1

Key Requirements in R15.08-1

- Focused on Risk Assessment (RA)
- Not prescriptive for Performance Levels (PL)
- Annex C for parameters and thresholds for specifying performance requirements
- Replanning of path shall not introduce hazards
- Typical requirements re:
  - Protective stops and E-stop
  - Collision avoidance and speed control
  - Stopping distance
  - Energy Control

Key Requirements in R15.08-1

- Presence-sensing safety functions may be suspended under 300 mm/s
- IMRs with attachments or manipulators:
  - Working space – consider the reach of attachments
  - Collision avoidance shall also monitor any extensions over the platform
  - Velocity limits need to also consider simultaneous motion, if capable
  - Stow configuration for manipulator
  - Attachments shall not introduce additional hazards
  - Stability needs to account for loads/dynamics of attachments
- AGVs with manipulators or Type C's with forks shall comply with B56/5 or ISO 3691-4

R15.08 - Writing Part 2

- Part 2 provides guidance for the Integrator.
- What information can you use?

For Information You Can Use:

See Information for Use

4 Risk Assessment

4.1 General

A robot system integrator shall perform a risk assessment. The integrator should seek the participation of the user when conducting the risk assessment.

The acceptable residual risk associated with expected use and foreseeable misuse of the IMR system shall be identified in the information for use.

Day 3: Intro to Mobile Robot Risk Assessment

Bob Bollinger, Dynamic Horizons

4.4.1. Specified Operating Environment

4.4.1. Specified operating environment

According to R15.08-1, the IMR manufacturer states the specified operating environment (SOE) in which its IMRs can reasonably be expected to operate safely. The IMR integrator may place additional limitations on the SOE beyond those specified by the IMR manufacturer. All limitations, including those stated by the IMR manufacturer accordance with R15.08-1, and any additional limitations specified by the integrator, shall be documented and provided in the information for use.

Day 2: When Safety Strategies Differ Between Integrator and End User

Paul Santi, FANUC

4.4.3. Classification of Zones

4.4.3. Classification of Zones

The documentation of the DOE shall include the classification of zones. Classification of zones establishes minimum requirements for the preparation of the zones so that the IMR(s) can safely operate. The IMR system integrator shall identify operations and requirements for the IMR system in the zones identified in its DOE, and these shall be documented and provided in the information for use.

Documentation of the procedures for safely occupying a zone by affected persons shall be provided by the IMR system integrator in the information for use.

5.1 General Safety Requirement for IMR Systems

5.1 General Safety Requirements for IMR Systems

IMRs used in an IMR system shall comply with the safety requirements of Part I of this document, including any additional attachments added by the integrator (see Part I, Sections 5.1, 5.2, and 5.4).

All IMR manufacturer's specifications, as described in the Information for Use for the IMR(s) being deployed, shall be followed.

If risks are introduced during integration that is not covered by the IMR manufacturer's Information for Use, the residual risk of the IMR system shall be reduced to an acceptable level.

5.2.2 Payload definition

5.2.2. Payload definition

The payload specification shall be defined for the intended operation of the IMR system and documented in the Information for Use (Clause 7).

The payload specification may include:

- maximum mass of the payload,
- maximum dimensions of the payload,
- allowable payload center of gravity,
- method of securing the payload, and
- identification of the allowable types or classification.

5.4.4 Interfacing with Stations

5.4.4 Interfacing with stations

The following requirements shall apply in addition to the requirements of 5.3.4.

Sufficient space shall be provided and maintained for stations. The space requirements shall be based on either

- the information for use provided by the IMR manufacturer, or
- a documented risk assessment.

Anticipated tasks and IMR operations for each specific deployment shall be reviewed to eliminate trapping and crushing possibilities within the hazard zone.

5.4.5. Interactions with affected persons

5.4.5.1 General

Areas of the facility where the IMR system operates shall be clearly defined and provided in the information for use.

Hazards arising from reasonably foreseeable interactions between the IMR system and affected persons shall be identified and their risks reduced to an acceptable level.

NOTE 1: Task-based interactions (3.1.3.7) are purposeful interactions between the qualified personnel and the IMR (see 5.4.5.2).

NOTE 2: Non-task-based interactions (3.1.3.8) can occur and are not necessarily reasonably foreseeable misuse.

5.4.6.2 Environmental features that can distort safety-related sensors

The DOE shall be provided within the specification of the safety-related sensors.

Limitations in future changes to the DOE (e.g., restrictions regarding the introduction of mirrors, retroreflectors, glass doors, etc.) shall be documented in the information for use.

NOTE 1: Some items of an environment, if introduced to the DOE after installation of the IMR system, could cause improper operation of sensor-based safety systems, thus introducing new hazards for affected persons. Such items could include, e.g., highly reflective objects, black bodies (surfaces that absorb all or nearly all light), retroreflectors, and transparent materials.

5.5.6. Control of Hazardous Energy

A means of isolating hazardous energy sources in the IMR system (e.g. disconnector, pressure relief device, energy isolation control system) shall be provided. Energy isolating devices shall be capable of being secured in the OFF (de-energized / open/isolated) position only. A means of locking or alternative means of controlling the hazardous energy shall be provided as described in ANSI/ASSP Z244.1.

Electrical systems shall be provided with a safe way to isolate and/or remove the power source from the equipment for maintenance and safe transport according to NFPA 79 or IEC 60204-1.

Requirements and instructions for the safe handling of power disconnects (e.g., supply disconnecting devices, and physical supports for powered brake systems) shall be included in the information for use. Alternative methods of hazardous energy control should be included in the information for use.

NOTE 1: Thermal, radiation and gravitational energy may be inherent and not normally dissipated through hazardous energy control methodologies. For example, an IMR on an incline being serviced with the brakes disengaged is still subject to gravitational energy.

NOTE 2: See also 5.12.4 for additional requirements for control of hazardous energy for maintenance tasks.

5.6.5 Performance

The results of a risk assessment performed on the IMR system and its DOE shall determine the required performance of the SRP/CS for each required safety function according to Annex C.

The IMR system shall have the required SRP/CS for each safety function according to the determined performance requirements. The SRP/CS performance of all safety functions shall be provided in the information for use, including specific identification of the criteria used to select the required performance for each safety function.

See also ANSI/RIA R15.08-1-2020, Annex C for parameters and thresholds for specifying a performance requirement.

5.12.4.3 Initial Start-Up

5.12.4.3 Initial start-up

Initial start-up shall be performed according to the initial start-up procedure (5.13.4.2).

Following initial start-up, verification testing of IMRs shall be conducted according to the IMR manufacturer's instructions in the information for use (Clause 7).

5.12.5.2 IMR System V&V

Verification and validation (Clause 6) testing of the integrated IMR system within the DOE shall be conducted according to instructions provided in the information for use (Clause 7) to ensure that risk reduction measures operate as required. At a minimum, such testing shall be conducted in automatic mode according to 5.13.5.2.

NOTE 1: Verification and validation could include:

- validating that risk reduction measures function correctly in the application workflow(s) within the DOE;
- testing functions such as, e.g., stopping distance, sensor function;
- testing operation of system-wide safety commands;
- testing correct functioning of the operating modes of the IMR system.

NOTE 2: Some discrete tests of IMR functioning might have been conducted during pre-start-up or initial start-up verification. In this case, documentation of such tests should be included in the overall system verification and validation.

5.13. Maintenance and Repair

5.13.1 General

Instructions for anticipated maintenance and repair (e.g., manuals), shall be provided in the information for use, and shall include safe working practices, and the training required to achieve the necessary skill level of qualified and authorized personnel maintaining the IMR system.

NOTE: “Safe working practices” and “necessary skill level” can include an understanding of when a given task exceeds the available skill level, and the integrator or manufacturer should be contacted to complete the task.

Information for use shall include requirements for periodic functional testing of the-safety related parts of the equipment (e.g., emergency stop device, enabling device) to ensure proper operation.

5.13.6 Validation after Maintenance/Repair

A means (e.g., process, procedure, equipment) shall be provided to validate safe operation of the IMR system after routine maintenance or repair, including removal/replacement of any FRU.

For all anticipated maintenance use cases that could affect safety, information/tools required to perform software/firmware updates (e.g., to the IMR(s), fleet manager, or other related parts of the IMR system) shall be provided.

Information for use shall include instructions that components of the IMR system that have undergone maintenance shall not be returned to service from maintenance until such validation is performed. Documentation of the procedures for validation shall be provided by the IMR system integrator in the information for use.

6.2 Verification and Validation Methods

Annex E lists the requirements of Clause 5 and the acceptable means by which to verify and validate whether these requirements have been met. Using one or more of the methods below in accordance with Table E.1, each requirement shall be verified or validated, or both.

A. Visual inspection;
B. practical tests;
C. measurement;
D. observation during operation;
E. review of application-specific schematics, circuit diagrams and design material;
F. review of IMR operation-based risk assessment;
G. review of task-based risk assessment;
H. review of specifications and information for use, including SOE and DOE.

NOTE: See sections 3.1.3.7 and 3.1.3.8 for definitions related to task-based interactions. See sections 4.5.1 and 4.5.2 for risk assessment of interactions with affected persons.

6.4 Test pieces

Test pieces representing adult humans shall be used in lieu of human subjects when performing verification and validation testing of safety functions. Test pieces appropriate to test the stated detection capability of the sensor technology applied shall be used for this purpose. All relevant characteristics of the test piece(s) used shall be described and added to the information for use. Human-analog test piece(s) shall be tested in a number of orientations reflecting persons who are standing, sitting, kneeling, or lying prone.

7. Information for Use

Information for use shall contain all information and instructions necessary to ensure safe and correct use of the system and shall provide information and warnings to the user about any residual risks.

Information for use shall consist of items such as documents, signs, signals, symbols, or diagrams used to convey important safety-related information to the user.

The style and content of the different parts of the information for use should reflect the level of education, technical understanding, and competence of the intended reader. It should be written in a language appropriate for the intended user.

The information shall reflect both the intended use and reasonably foreseeable misuse of the integrated system.

Group participation

What potential risks do you see in this picture that may be different from a traditional risk assessment?

7.2 Instructional Handbook

The instruction handbook shall take into account the different phases of the use of the IMR system, including transport, installation, commissioning and programming, operational use, maintenance, abnormal and emergency situations, and where applicable decommissioning, dismantling, and disposal.

The instruction handbook shall include the interfaces (physical, mechanical, functional) between components of the IMR system. This includes components that were supplied by the integrator, supplied by others and pre-existing equipment.

The instruction handbook shall include the information for use from the component manufacturers, either directly or by reference.

WHY DO DOGS LIVE LESS THAN HUMANS?

”People are born so that they can learn how to live a good life — like loving everybody all the time, and being nice, right?”

”Well, dogs already know how to do that, so they don’t have to stay for as long as we do.”

- Live simply.
- Love generously.
- Care deeply.
- Speak kindly.

In Memorial – Michael “Big Bad” Wolfe passed due to Covid on April 15, 2022.

- Trained in Columbus at Westside Barbell and was their first 800 lb. bench press!
- 2nd place at the Arnold Classic!
- Eat Competitively!
- He cared about everyone he met and is greatly missed.

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R15.08 – End User

- Part 3 will be for the End User
  - Input from End Users like You and OSHA, especially for Part 3
  - RIA TR R15.706, User Responsibilities?
  - How would OSHA want Part 3 to guide both the end user and the OSHA inspectors?

OSHA/ NIOSH/ A3 Alliance (Day 3)

- Dawn Castillo, NIOSH
- Carole Franklin, A3
- Hazen Price, OSHA

THANK YOU!

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