SAFE HRC SYSTEMS
HUMAN ROBOT INTERACTION FOR STARTERS

SICK
Sensor Intelligence.

Werner Zipperer

Productmanagement „Industrial Safety & Motion Control Sensors“

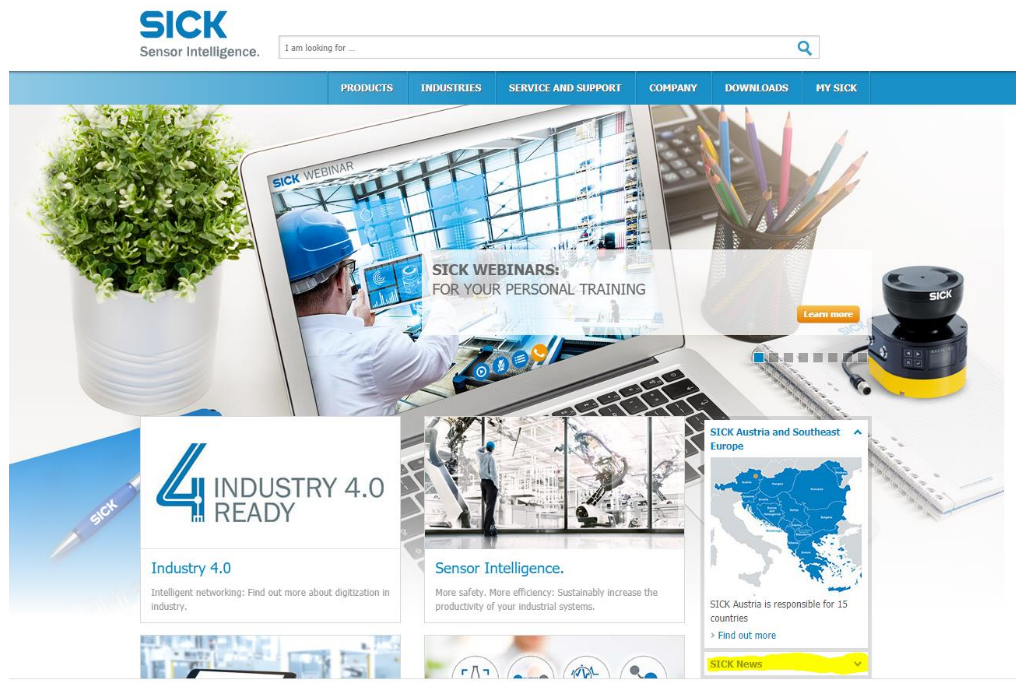
April 2021

REMARKS TO THIS WEBINAR

- This webinar will be recorded!

- If you would like to receive the **presentation** and / or the **recording** afterwards, we ask for your **consent in accordance with the GDPR**!

https://s.sick.com/newsletter_registration_at-de



AGENDA / CONTENT

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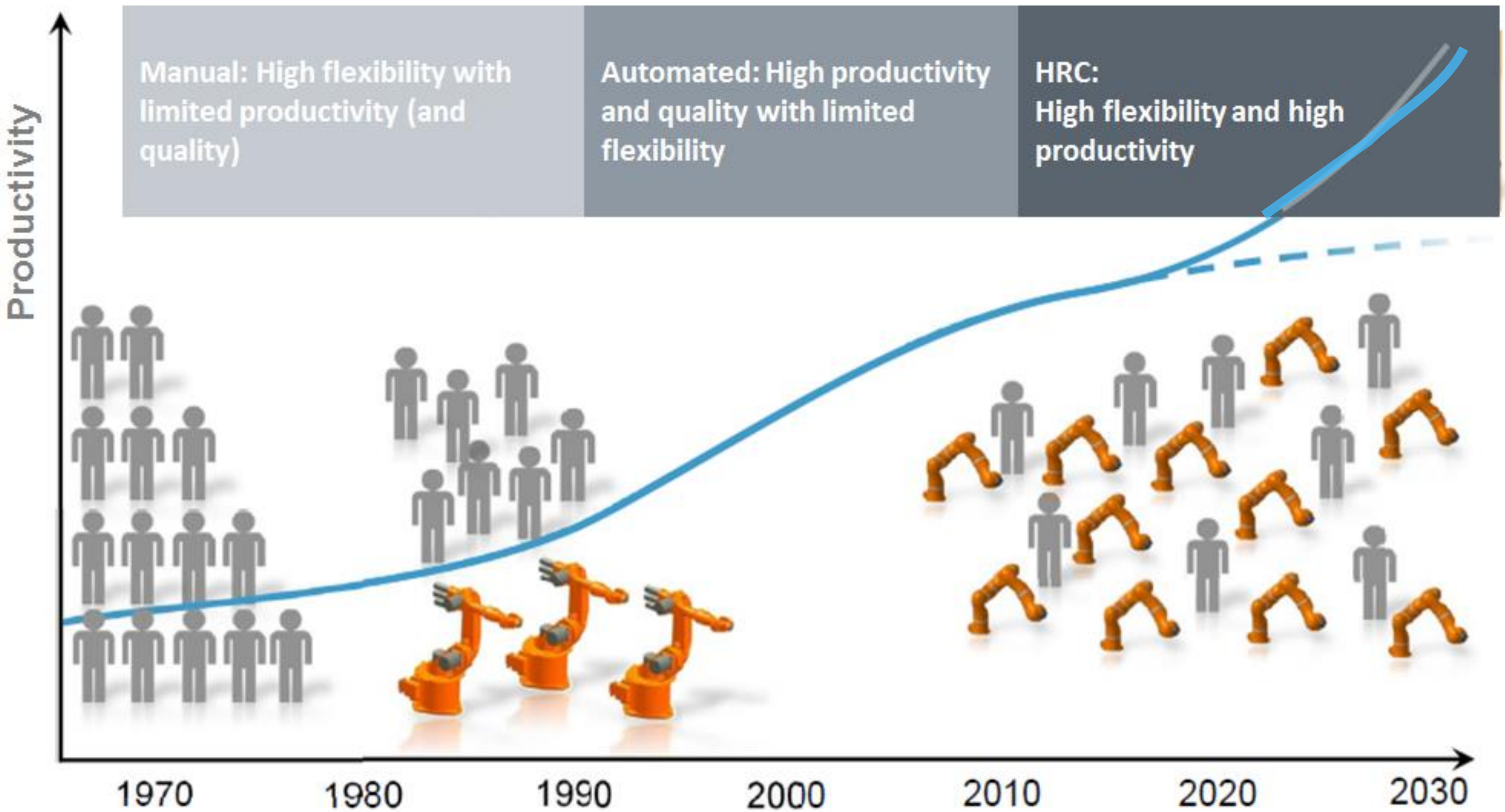
- Marketoverview Robotic
- Terminology
- Trends to HRC
- Standards
- Possible HRC Interactions
- Safety Distances
- Information to ISO/ TS 15066
- Technical Execution
- Riskassessment

Marketpotential for collaborative Robots (global)

Productivity Growth by application of Robots



Source: Daimler

Robot Market
Figures & Facts

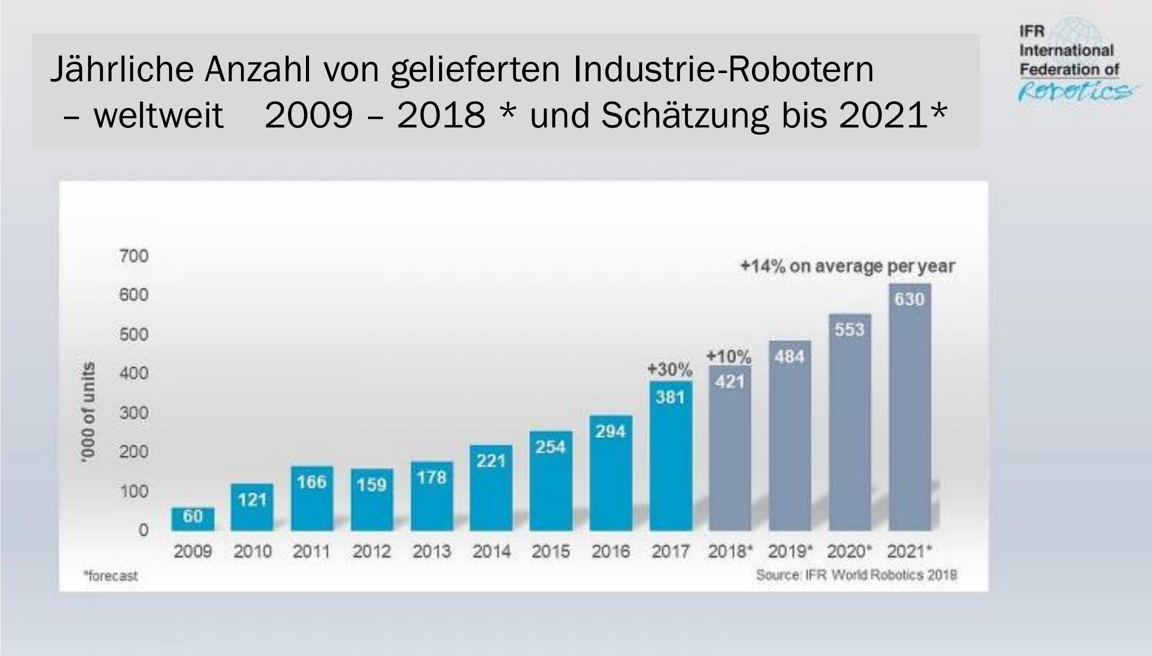
High strategic importance

- Currently more than 2 million robots installed worldwide
- Expectations are more than 14% annual average growth from 2020 onwards, by 400.000 units

Industries

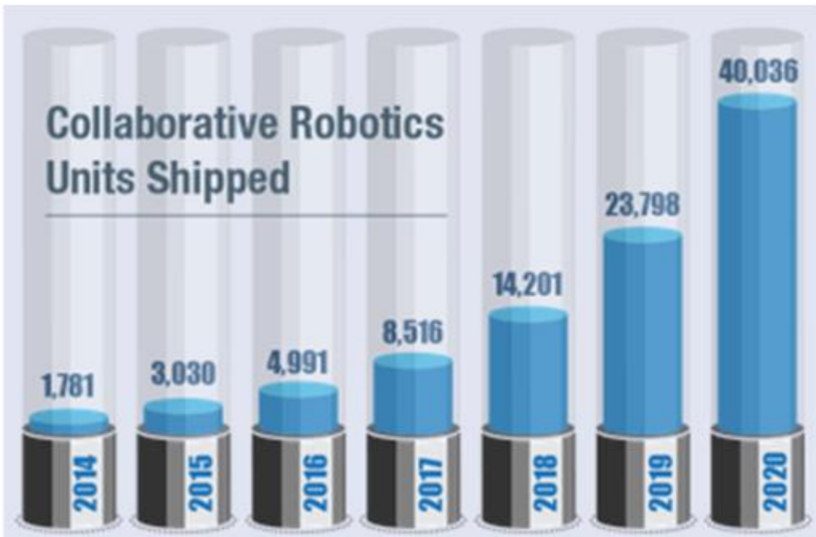
Main drivers:

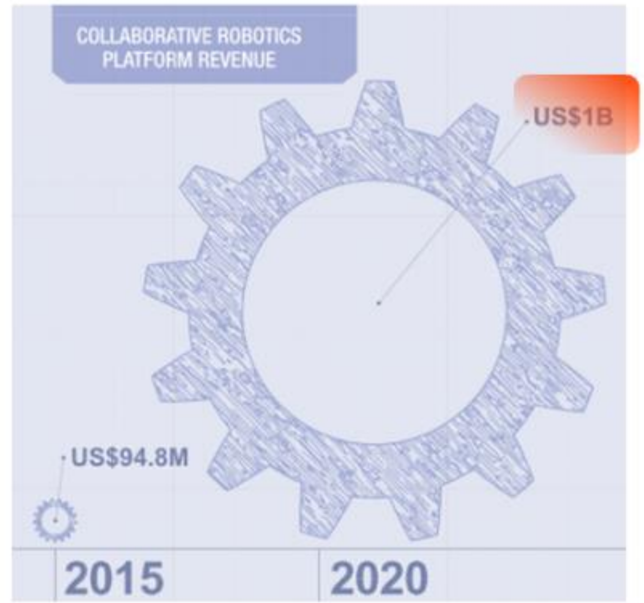
- Automotive- und Electronicindustrie
  - Mainly handling and assembly
- Consumer Goods
  - Handling / Palletizing
- Machinebuilding
  - Handling and assembly



- *IFR statistical department, world robotics 2018

Marketpotential for collaborative Robots (global)





Future collaborative Market (ABI Research)

Industries: Automotive, Machinebuilding, Electronic, Customer Goods and Logistic applications

ROBOT

Generic DEFINITION: What is a Industry-Roboter ?

Definition according to ISO 8373:

- Industry Robot = Manipulator
  - automatically controlled
  - programabler
  - 3 or more axis
  - versatilely and universally applicable
  - stationary or mobile applications
  - designed, to be used in industrial automation applications

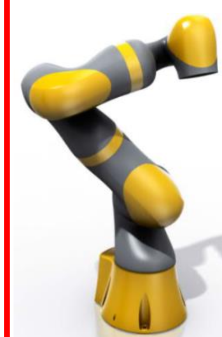
Imehrachs- Roboter

Portal Roboter

SCARA Roboter

Delta Roboter

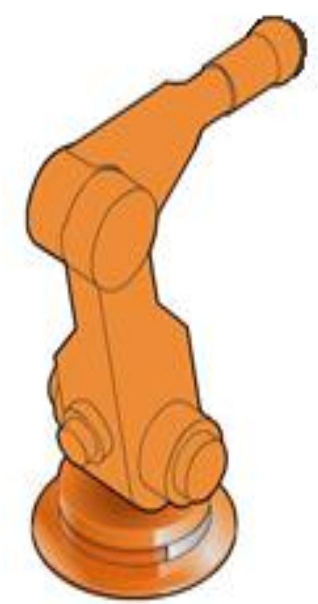
Cobots



ROBOT SYSTEMS
TERMINOLOGY

- (Industrial) Robot-Systems consist of:

ROBOT-SYSTEMS



ROBOT
Incomplete Machine

Safety Equipment

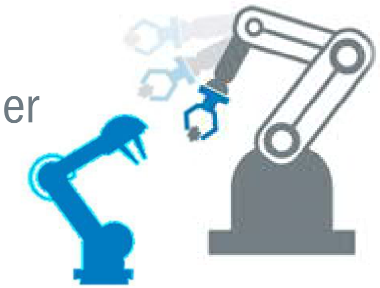
Robot Controller

End-Effector
(e.g. gripper), holder,
tools, workpiece

HUMAN ROBOT INTERACTION

TARGET

is, to combine the strengths of humans and robots together



Detection of deviations from the working process

Sensitive recognition

Fine motor skills

Power of abstraction (reaction to unforeseeable circumstances)

Human – Robot – Collaboration

Speed

Force

Performance capabilities

Repeatability

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What differentiates HRC applications from “classic” (standard) robot applications?

HRC applications place new demands on security:
Essential Differentiations:
- Collisions betweens robots and humans are allowed
- However, they must not lead to any injuries

Preconditions therefore are:
- The robots used must be enabled by suitable measures to either detect the collision beforehand or at the latest when it comes into contact with humans and to initiate safety measures.

DIFFERENTIATION BY APPLICATION SCENARIOS

OVERVIEW ON TODAYS APPLICATION SCENARIOS

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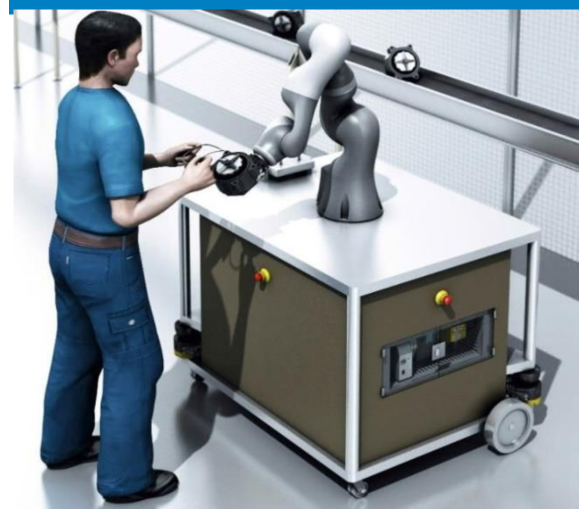
Realization with standard industrial robots, as well as with COBOTS

Realization only with COBOTS

COEXISTENCE	COOPERATION	COLLABORATION



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WHICH ROBOTS ARE SUITABLE?

FUNCTIONAL SPECS FOR ROBOTS

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COOPERATION	COLLABORATION

Industrial-Robots with safe rated kinematics

- Safe rated position
- Safe rated stopp
- Safe rated speed
- Safe rated area

Lightrobot - COBOTs

- Safe rated kinematics
- Safe rated force and torques
- capacitive / tactile skin for collision detection

WHICH ROBOTS ARE SUITABLE?

ROBOT-Types FOR COLLABORATION WITH HUMANS

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COBOTS – SUITABLE ROBBOTS FOR DIRECT INTERCATION WITH HUMANS

LEICHTROBOTER MIT DREHMOMENT- / KRAFTBEGRENZUNG	ROBOTER MIT TAKTILEN ODER KAPAZITIVEN OBERFLÄCHEN

Technical Restrictions

- reduced payload→ max. 35kg
- Higher moving speeds are only applicable with additional safety sensors with a higher reach

DIFFERENTIATION BY APPLICATION SCENARIOS

OVERVIEW ON TODAYS APPLICATION SCENARIOS

97% of all applications

COEXISTENCE

COOPERATION

3% of all applications

COLLABORATION

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Standards for HRC applications

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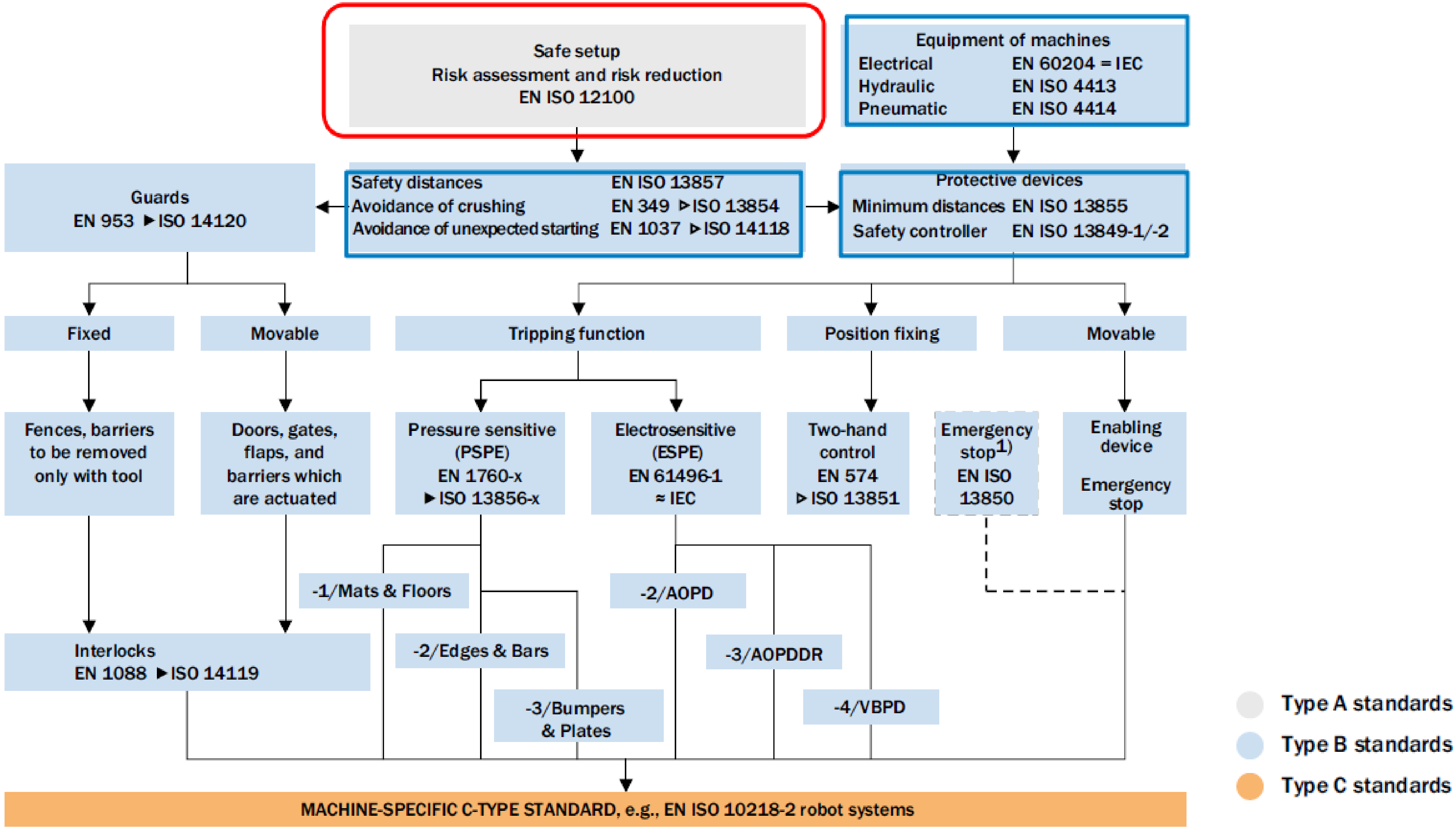

Standards for HRC applications
Overview

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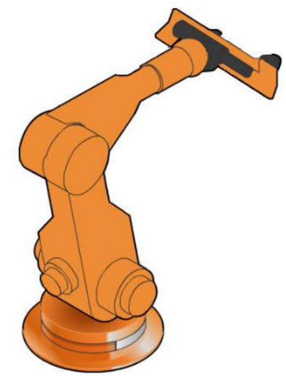
- DIN EN ISO 10218 Industry Robots part 1 und 2

  – DIN EN ISO 10218-1:2012-01
  Industry Robots- Safetyrequirements- PART1: Robot

  – DIN EN ISO 10218-2:2012-06
  Industry Robots- Safety Requirements- P A R T 2: Robotsystems and Integration



- DIN ISO/TS 15066 Robots und Robotic Devices– Collaborative Robots

  ▸ Actual limits are conservatively determined (= safety equipment is required In most of the cases)

  – DIN ISO/ TS 15066:2016
  Robots and Robotic Devices - Collaborative Robots

TS 15066 is a completion to EN ISO 10218-2 :

- As a guide for the implementation of collaborative robot applications
- Especially when humans and robots share a workspace at the same time

CONTENT OF DIN EN ISO 10218- 2

Overview

Other important content and information

▸ Collaboration

- only for predefined tasks
- only permitted if necessary protective measures are active
- only for robots that are specially designed for collaborative operation and conform to ISO 10218-1. This does not necessarily have to be a real COBOT, some manufacturers then modify standard robots in terms of safety, for example by covering them with padding or tactile skin.

Integrator Responsibility:

- specify in the user information the protective devices and the operating mode selection, which are required for the collaborative operation.
- Perform a risk assessment that takes into account the entire task to be performed together and the shared workspace.

COMMENT: Refer to Attachment E of EN ISO 10218-2 for examples

CONTENT OF DIN EN ISO 10218- 2
Overview

Robots that are integrated into a collaborative workspace must
meet the requirements of ISO 10218-1;

Non-separating protective devices required for presence detection
must meet the requirements of 5.2.2;

Additional non-separating protective devices in a
Collaborative workspace must meet the requirements of 5.2

The technical protective measures must be designed so that they prevent or recognize a progressive approach of a person into a protected area beyond the collaborative workspace. The intrusion into the protected area beyond the collaborative workspace has to result in a robot to stop and all dangerous machine functions have to be terminated.

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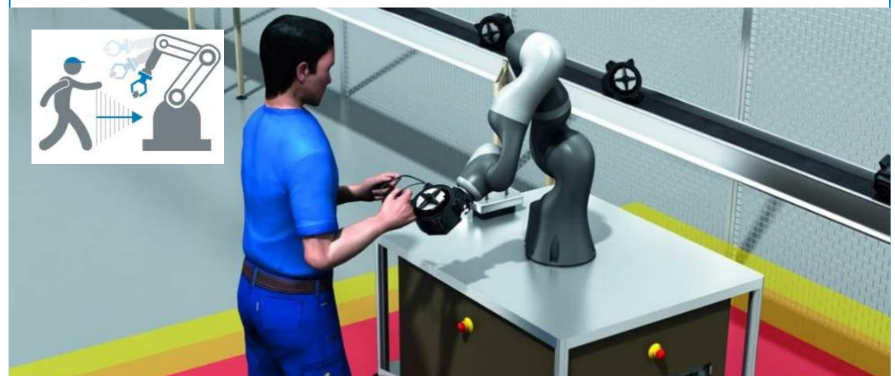
5.2.2 Performance requirement

Safety related parts of a control shall be deigned so that they comply with PL =d with category 3 as described in ISO 13849-1:2006 or so that they comply with SIL2 as described in IEC 62061.

HUMAN-ROBOT COLLABORATION
NORMATIVE METHODS

The following 4 methods / measures are described in detail in ISO 10218 and ISO / TS 15066

SAFETY RATED MONITORED STOP SS2



SPEED AND DISTANCE CONTROL

HANDGUIDING

POWER AND FORCE LIMITATION

HUMAN-ROBOT COLLABORATION

- The four methods for collaborative applications

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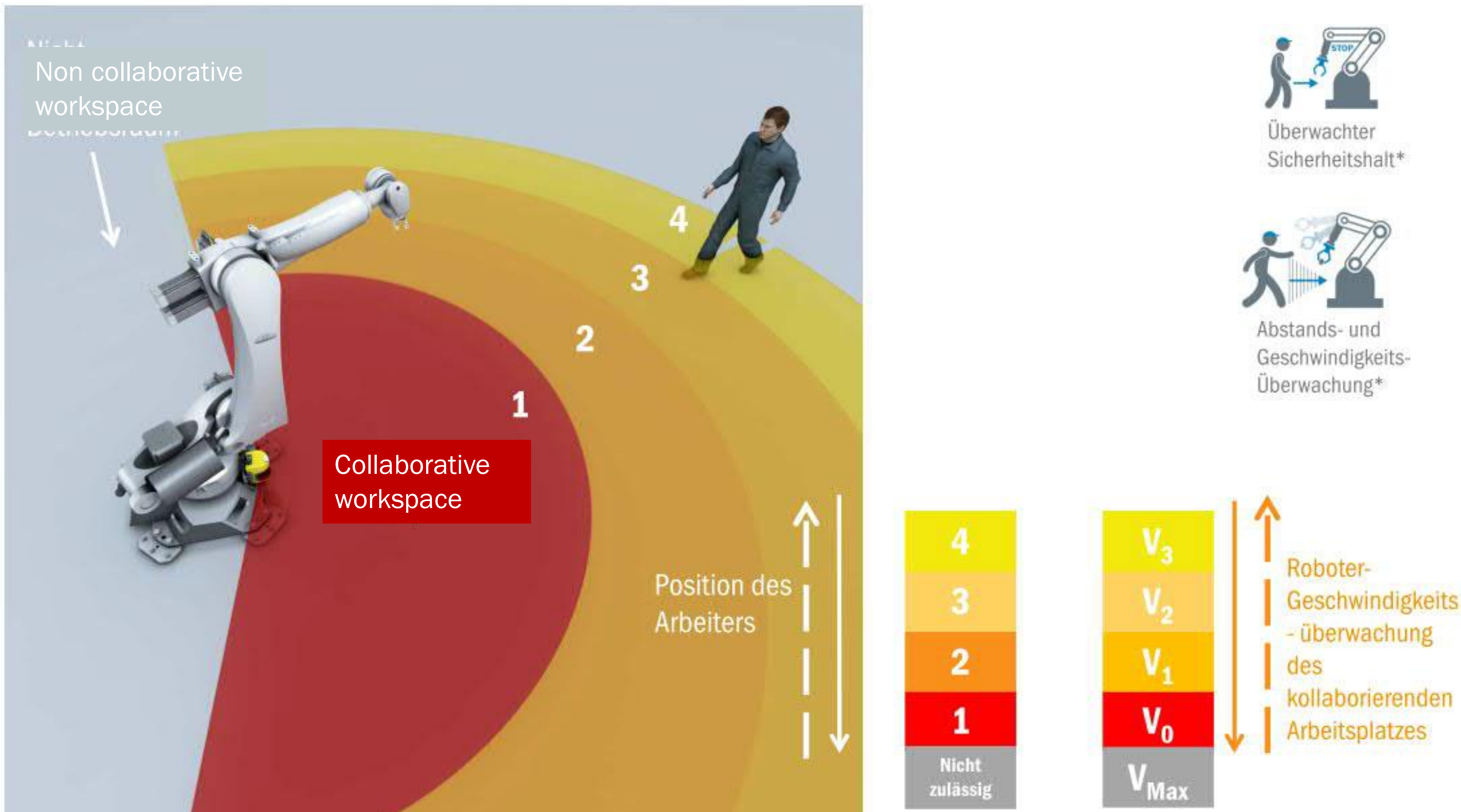
Method	Safety Requirements
 Hand guiding	Humans may only approach the robot when it is at a standstill. Manual guidance of the robot using a guidance device and an enabling button at a safe speed. Level of speed depends on the risk assessment. A clear, unobstructed view of the entire collaboration space is required. When the enabling button is released, a safety rated monitored stop takes place.
 Speed and distance control	Use of non-separating protective device to implement a safe Distance control, e.g. with a safety laser scanner or 3D safety camera. Speed is dynamically adjusted depending on the distance. Level of the speed and the required safety distance following the risk assessment. *[1]
 Safety rated monitored stop	When a person enters the collaborative workspace, a safety rated monitored stop is triggered. When leaving the collaborative workspace, Robot can resume its operation. The need for a manual reset of protective device or automatic restart of the robot, as well as the level of the speed results from the risk assessment. *[1]
 Power and force limitation	Human and robot are sharing collaborative workspace at the same time. Collision between humans and robots in compliance with the biomechanical limit values according to TS 15066 is permitted. Force and torque monitoring through tactile protection devices, torque sensors. Adherence to safe rated monitored speed. *[1]

*[1] **Robots have to be used which comply to ISO 10218-1**

HUMAN ROBOT COLLABORATION

Possible combinations of methods for collaborative interaction



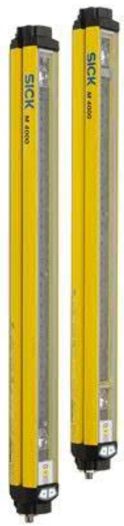
(*) ISO 10218-2/TS 15066

SAFETY DISTANCE

EN ISO 13855: Safety Distance

„SAFETY DISTANCE“

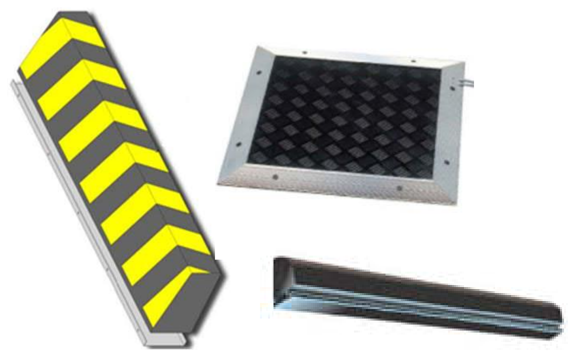
for



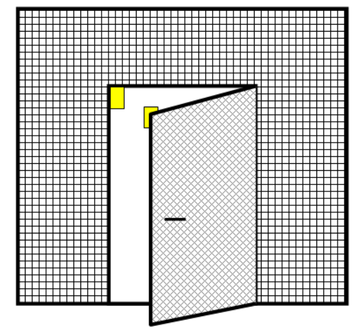
AOPD

AOPDDR

Pressure Sensitive Devices



Physical guards, fences & barriers



Contactless sensing

SAFETY DISTANCE EN ISO 13855

Basic Formula

Definition of the standard

Allgemeine Berechnungsformel

$$S = (K \times T) + C$$

S_{min} = 100mm

EXCEPTION

A C-Standard exists and determines the safety distance for a specific application

with

S : minimum distance [mm]

T : stopping / run down time of the overall system [s]

C : is the additional distance that represents the intrusion into the hazard zone [mm]

K : Parameter for the approach speed [mm/s]

HINT: Further detailed information refer to our guideline „Six Steps to a Safe Machine“

5.5.4.2.1 General

If the separation distance between a hazardous part of the robot system and any operator falls below the protective separation distance, then the robot system shall:

a) initiate a protective stop;
b) initiate safety-related functions connected to the robot system in accordance with ISO 10218-2:2011,

SAFETY DISTANCE
Info from ISO/TS 15066

The possibilities with which the control system of the robot can avoid violation of the safety distance include amongst others:

- speed reduction, possibly followed by a transition to a safe rated monitored stop (refer to 5.4.1)
- Following an alternative path, where the safety distance is not violated thereby continuing with active speed and distance control
- If the actual distance corresponds to the safety distance or exceeds it again, the robot movement may be resumed.

Abstands- und Geschwindigkeits-Überwachung*

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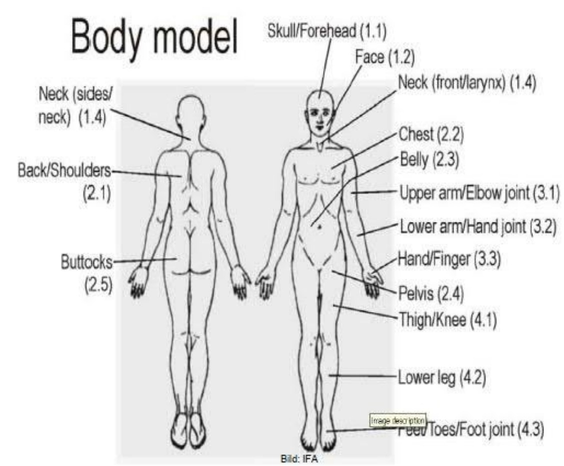
- Collision risks had to be determine
- Biomechanical stress effects due to collision had to be limited

- What are tolerable stress effects?
  - Pain threshold
  - Entry of injury
    - body stress
- First thresholds for stress effects as an orientation:
  - Clamping / Squeezing force
  - Push force
  - Pressure / surface pressure
- Power threshold per body regions

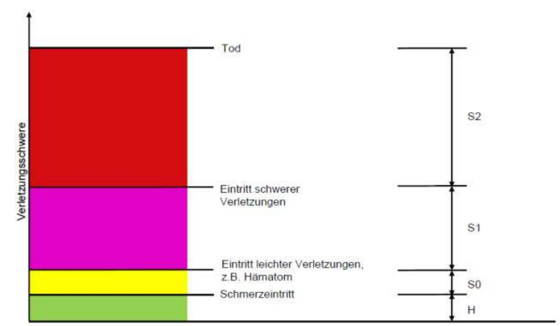


ISO/ TS 15066

EMERGE OF ISO/ TS 15066

Quelle: ifa

- Measuring the transition from an increasing. Feeling of pressure into an initial feeling of pain.
- Research project of the Gutenberg University Mainz in cooperation with the IFA
- Cadastral creation based on a body model with 15 individual body areas
- Examination of 29 body points
- Development of an automatic pressure algometer, when the pain threshold was reached the people showed through pressing a push button.
- By a number of subjects of around 100 people about 9000 usable pain threshold measurements were taken



ISO/ TS 15066
DEVELOPING A BODY MAP

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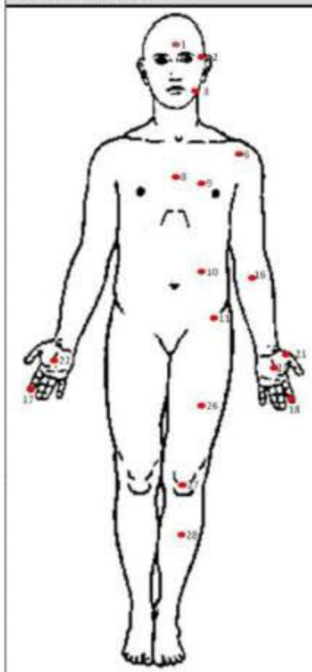
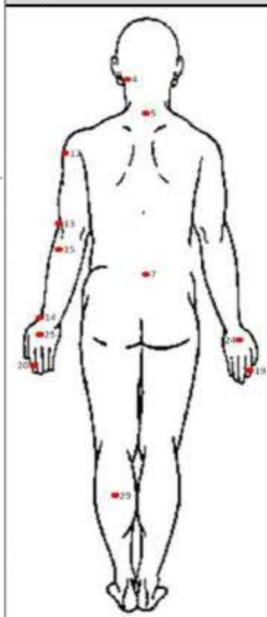
Körpervorderseite	Spezifische Lokalisation	Körperregion
1	Stirnmitte	Schädel/Stirn
2	Schläfe	Schädel/Stirn
3	Kaumuskel	Gesicht
6	Schultergelenk	Rücken/Schultern
8	Brustbein	Brust
9	Brustmuskel	Brust
10	Bauchmuskel	Bauch
11	Beckenknochen	Becken
16	Armnerv	Oberarm/Ellenbogen
17	Zeigefingerbeere d	Hand/Finger
18	Zeigefingerbeere nd	Hand/Finger
21	Daumenballen	Hand/Finger
22	Handinnenfläche d	Hand/Finger
23	Handinnenfläche nd	Hand/Finger
26	Oberschenkelmuskel	Oberschenkel/Knie
27	Kniescheibe	Oberschenkel/Knie
28	Schienbein	Unterschenkel



d	Dominante Körperseite
nd	Nicht dominante Körperseite

The skull, the forehead, the face are critical areas !!!

Körperrückseite	Spezifische Lokalisation	Körperregion
4	Halsmuskel	Hals (Seiten/Nacken)
5	Dornfortsatz 7. Halswirbel	Hals (Seiten/Nacken)
7	Dornfortsatz 5. Lendenwirbel	Rücken/Schultern
12	Deltamuskel	Oberarm/Ellenbogen
13	Oberarmknochen	Oberarm/Ellenbogen
14	Speichenknochen	Unterarm/Handgelenk
15	Unterarmmuskel	Unterarm/Handgelenk
19	Zeigefingerendgelenk nd	Hand/Finger
20	Zeigefingerendgelenk d	Hand/Finger
24	Handrücken d	Hand/Finger
25	Handrücken nd	Hand/Finger
29	Wadenmuskel	Unterschenkel



d	Dominante Körperseite
nd	Nicht dominante Körperseite

Body Map of DGUV-Information, FB HM-080 Entwurf 04/2017

ISO/ TS 15066

DEVELOPING A BODY MAP

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Kritische Zone

Körperlokalisation			Quasi statischer Kontakt (Klemmen)		Transienter Kontakt (Freier Stoß)	
Spezifische Lokalisation		Körperregion	Spitzendruck p_S [N/cm²] (Anmerkung 1)	Kraft F_S [N] (Anmerkung 2)	Spitzendruck P_T Faktor (Anmerkung 3)	Kraft F_T Faktor (Anmerkung 3)
1	Stirnmitte	Schädel und Stirn	130	130	Kein	Kein
2	Schläfe		[illegible]			
3	Kaumuskel	Gesicht	110	65		
4	Halsmuskel	Nacken	140	150	2	2
5	Dornfortsatz 7. Halswirbel		210			
6	Schultergelenk	Rücken und Schultern	160	210		
7	Dornfortsatz 5. Lendenwirbel		210			
8	Brustbein	Brust	120	140		
9	Brustmuskel		170			
10	Bauchmuskel	Bauch	140	110		
11	Beckenknochen	Becken	210	180		
12	Deltamuskel	Oberarm und Ellenbogen	190	150		
13	Oberarmknochen		220			
14	Speichenknochen	Unterarm und Handgelenk	190	160		
15	Unterarmmuskel		180			
16	Armnerv		180			
17	Zeigefingerbeere d	Hand und Finger	300	140		
18	Zeigefingerbeere nd		270			
19	Zeigefingerendgelenk d		280			
20	Zeigefingerendgelenk nd		220			
21	Daumenballen		200			
22	Handinnenfläche d		260			
23	Handinnenfläche nd		260			
24	Handrücken d		200			
25	Handrücken nd		190			
26	Oberschenkelmuskel	Oberschenkel und Knie	250	220		
27	Kniescheibe		220			
28	Schienbein	Unterschenkel	220	120		
29	Wadenmuskel		210			

ISO/ TR 15066
INFORMATION FROM ISO/ TS 15066

What needs to be considered when planning the HRC application:

Select a suitable robot for HRC
- Safety functions (position, speed, force, moment, etc … ..)
- Operation mode selection with enabling switch for operating mode manual guidance
- Control with PLd categorie 3

- Design measures:
  - Limitation of the range of motion
  - Exclusion of large, heavy and angular workpieces
  - Prevent contact with the head / neck area
  - Flat contours, no shear points or edges or tips
  - Cushionings

What needs to be considered when planning the HRC application:

- Consideration of interaction with humans
  - conscious / unconscious reach into the working area
  - Process monitoring (zB bending over)
  - Picking up parts that fall out during the process
  - Bumping on the robot, tool and workpiece

- Suitable workplace design:
  - Workplace lightning
  - Stability (prevention of slipping, stumbling, etc ...)
  - Instructed staff
  - Taking into account the presence of third parties

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In consultation with the operator, the integrator should identify and document the specific collaborative tasks which should be carried out with the integrated system

- Collaborative tasks are characterized by:

  Frequency and duration of operator presence in the collaborative workspace with a moving part of the robot system.

  Transition between collaborative and non-collaborative operations

  Automatic resumption of robot movement after the minimum distance is reached again

  Tasks that require more than one operator

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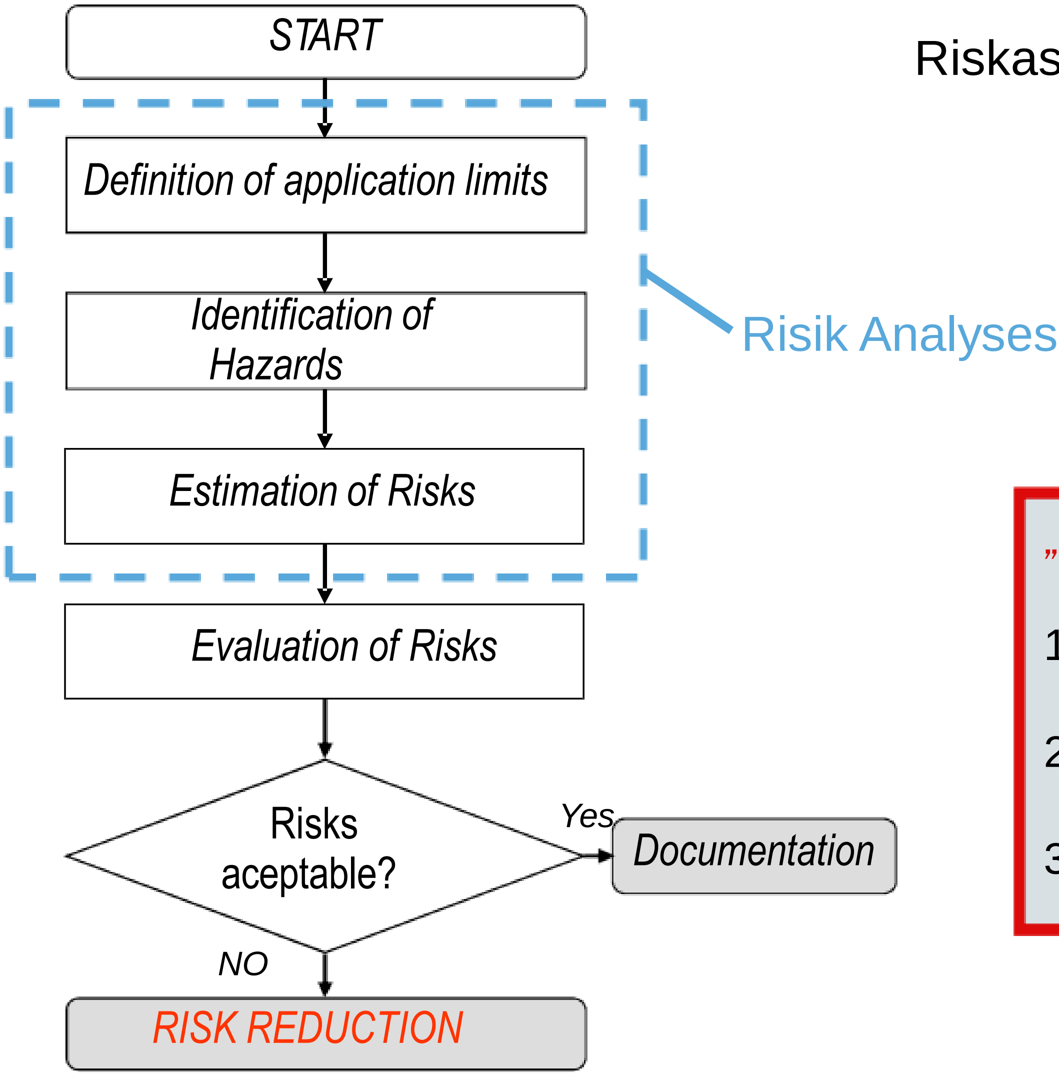
4.3.1 General

Because a robot system is always integrated into a particular application, the integrator shall perform a risk assessment to determine the risk reduction measures required to adequately reduce the risks presented by the integrated application. Particular attention should be paid to instances where safeguards are removed from individual machines in order to achieve the integrated application.

Risk assessment enables the systematic analysis and evaluation of the risks associated with the robot system over its whole lifecycle (i.e. commissioning, set-up, production, maintenance, repair, decommissioning).

Risk assessment is followed, whenever necessary, by risk reduction. When this process is repeated, it gives the iterative process for eliminating hazards as far as practicable and for reducing risks by implementing protective measures.

EXECUTION - RISIKASSESSMENT



Riskassessment according to EN-ISO 12100

„3-Step-Principle“

1. Safe Design
2. Technical protective measures
3. Administrative measures

HUMAN ROBOT COLLABORATION

Significant Hazards

- Squeezing between gripper and static parts of environment

- Squeezing between workpiece and static parts of environment

- Catching, squeezing at robot arm

- Catching, squeezing at robot gripper or openings in the workpiece

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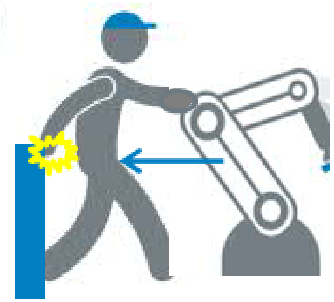
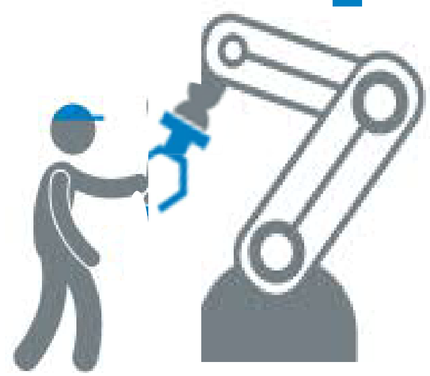
- Squeezing between robot joints and static parts of the environment

- Squeezing between robot arm and static parts of environment



- Pinching of fingers at the robot gripper or openings in the workpiece



RISKASSESSMENT FOR HRC APPLICATIONS

OVERVIEW OF RELEVANT SUBJECTS FOR RISK REDUCTION

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EVERY APPLICATION IS UNIQUE AND REQUIRES A SEPARATE RISK ASSESSMENT!

ROBOT APPLICATION

4 METHODs

- Hand Guiding
- Safety Rated Monitored Stop
- Speed- and Distance Control
- Power- and Force Limitation by inherent design of Robot and its controls

ROBOT-SYSTEM

ROBOTER Incomplete machine

Safety Equipment

Robotcontroller

End-Effector (z.B. Gripper), Tools, Workpiece

Werner Zipperer

Produktmanagement „Industrial Safety & Motion Control Sensors“

werner.zipperer@sick.at