SAFETY REQUIREMENTS AND STANDARDISATION FOR ROBOTS: SOFTWARE DO'S AND DON'TS

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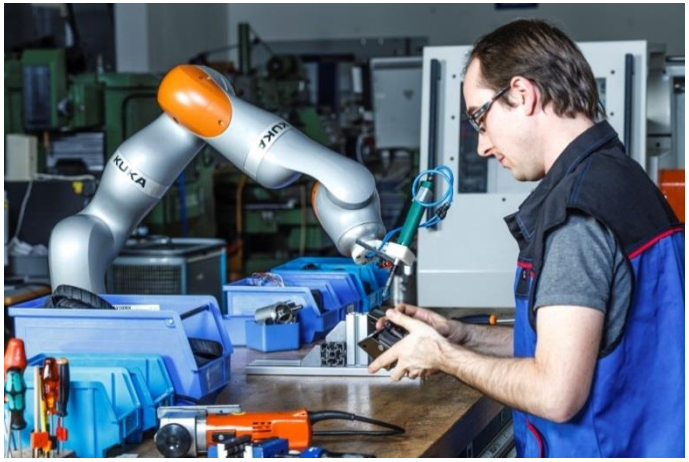
Safety as a key factor for bringing innovative robots onto the market

- Current trends in robotics:
  - Collaborative robots and robotic co-workers
  - Modular, reconfigurable systems
  - Increase in complexity of control systems and software
- Challenges for creating and selling new products:
  - Safety and reliability of new robotic applications needs to be guaranteed
  - Legal requirements and safety standards need to be fulfilled



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AGENDA

- European Directives on product safety
- Applicable standards for industrial and service robots
- Requirements for “safe software”
- Safety standardisation at ISO

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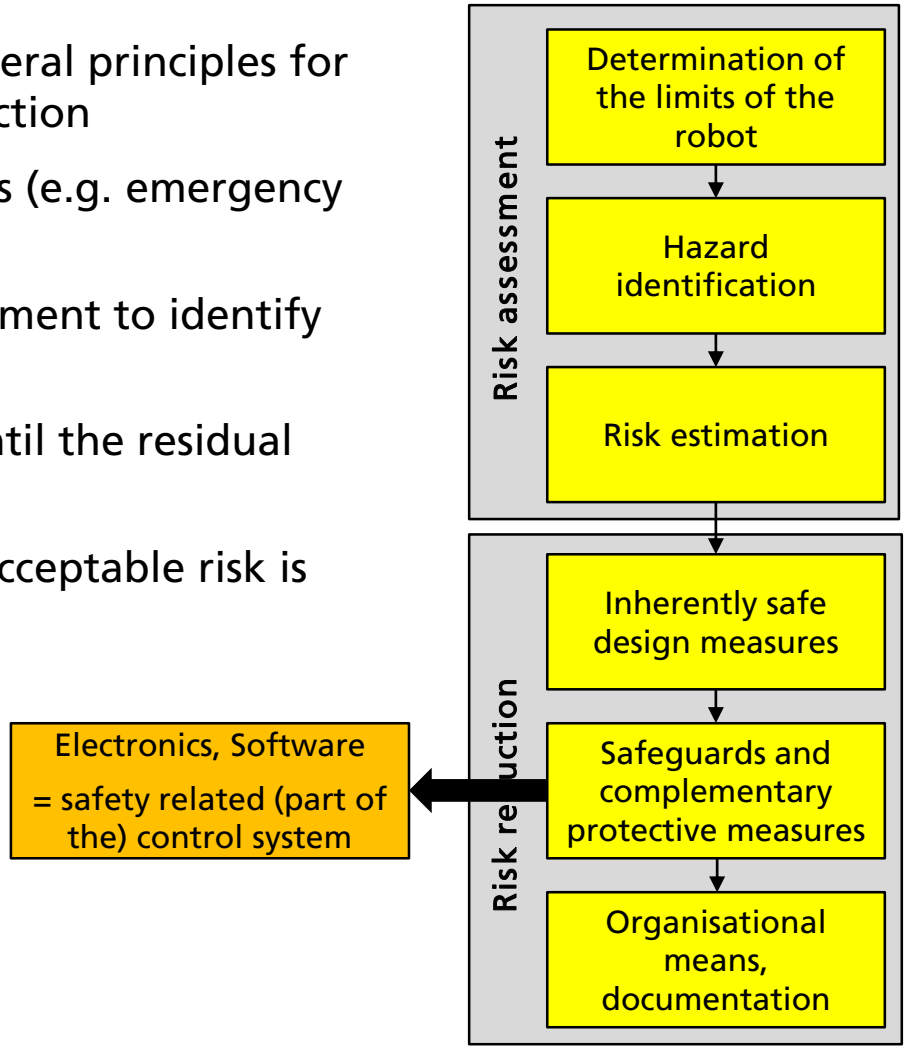
European directives on product safety

- All products put into circulation in the EU (manufactured, sold, imported, operated, etc.), have to fulfill applicable EU directives
  - Example: Machinary Directive (2006/42/EG), Low Voltage Directive (2006/95/EC), EMC-Directive (2004/108/EG)
    - Containing very general requirements for products
    - Conversion into national law (e.g. “Produktsicherheitsgesetz” in Germany)
- Reference to a list of “harmonized standards”
  - Detailed safety requirements
  - Application voluntarily but recommended
  - Presumption of conformity: If all harmonized standards of a directive are fulfilled it is presumed that the directive itself is fulfilled
- If all requirements from EU directives are fulfilled, a CE mark can be applied

Applicable standards: Risk assessment and risk reduction

- ISO 12100 – Safety of machinery – General principles for design – Risk assessment and risk reduction
  - General requirements for machines (e.g. emergency stop buttons, start-up, …)
  - Obligation to perform a risk assessment to identify unacceptable risks
  - Reduction of unacceptable risks until the residual risk is acceptable
- Manufacturer has to decide what an acceptable risk is



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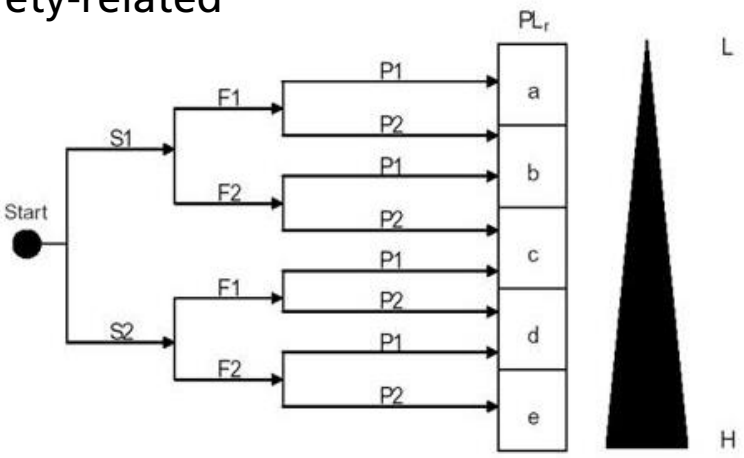
Applicable standards: Control system performance

- ISO 13849-1 – Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
  - Introduces required performance levels (PL) for safety-related control systems (e.g. velocity and position control, collision avoidance, stability control, etc.)
  - Higher PLs require redundant systems, well-proven components and high diagnostic coverage
- IEC 62061 – Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
  - Definies safety integrity levels (SIL) for safety-related control systems
  - Conversion between PLs and SILs possible
  - Applicable also to software functions
- Use of risk graphs to evaluate severity and likeliness of harm



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Applicable standards: Industrial robots

- ISO 10218-1 – Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots Requirements for the design of manipulators for industrial environments
  - Examples: mechanical and electrical design, pendant controls, operational modes, etc.
- ISO 10218-2 – Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration
  - Requirements for integrating industrial robots into automation systems
  - Examples: Collaborative modes like monitored stop, hand guiding, velocity or force control
- ISO/TS 15066 – Robots and robotic devices – Collaborative robots
  - Specification of tolerable force and pressure during collisions for different body parts
  - Instructions to measure impact forces and verify limits

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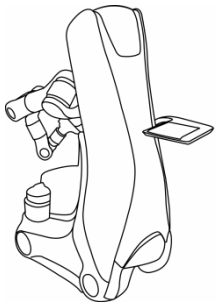
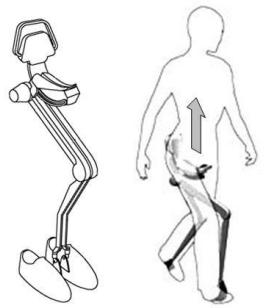
Applicable standards: personal care robots

- ISO 13482 – Robots and robotic devices – Safety requirements for personal care robots
- Personal care robot: *"service robot that performs actions contributing directly towards improvement in the quality of life of humans, excluding medical applications."*
  - Examples in the standard: Mobile servant robots, person carrier robots, physical assistant robots
  - Requirements for mechanical and electrical design
  - Requirements for control system design and performance
- New concepts in the area of service robots
  - Shared workspace is the standard case
  - Intended contact between robot and human
  - Risks related to autonomous actions and decisions





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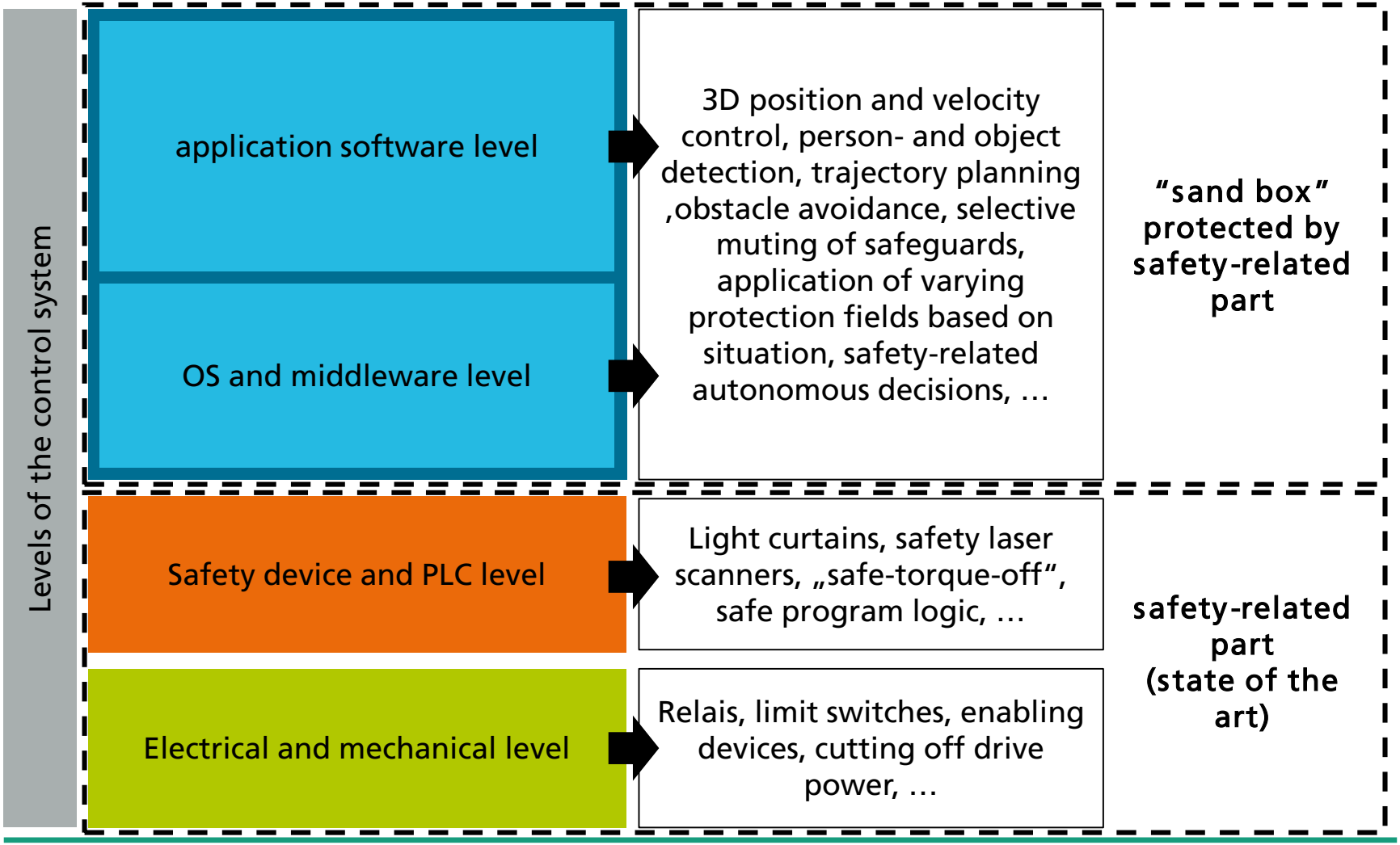
Safe software: Boundaries of the safety-related control system



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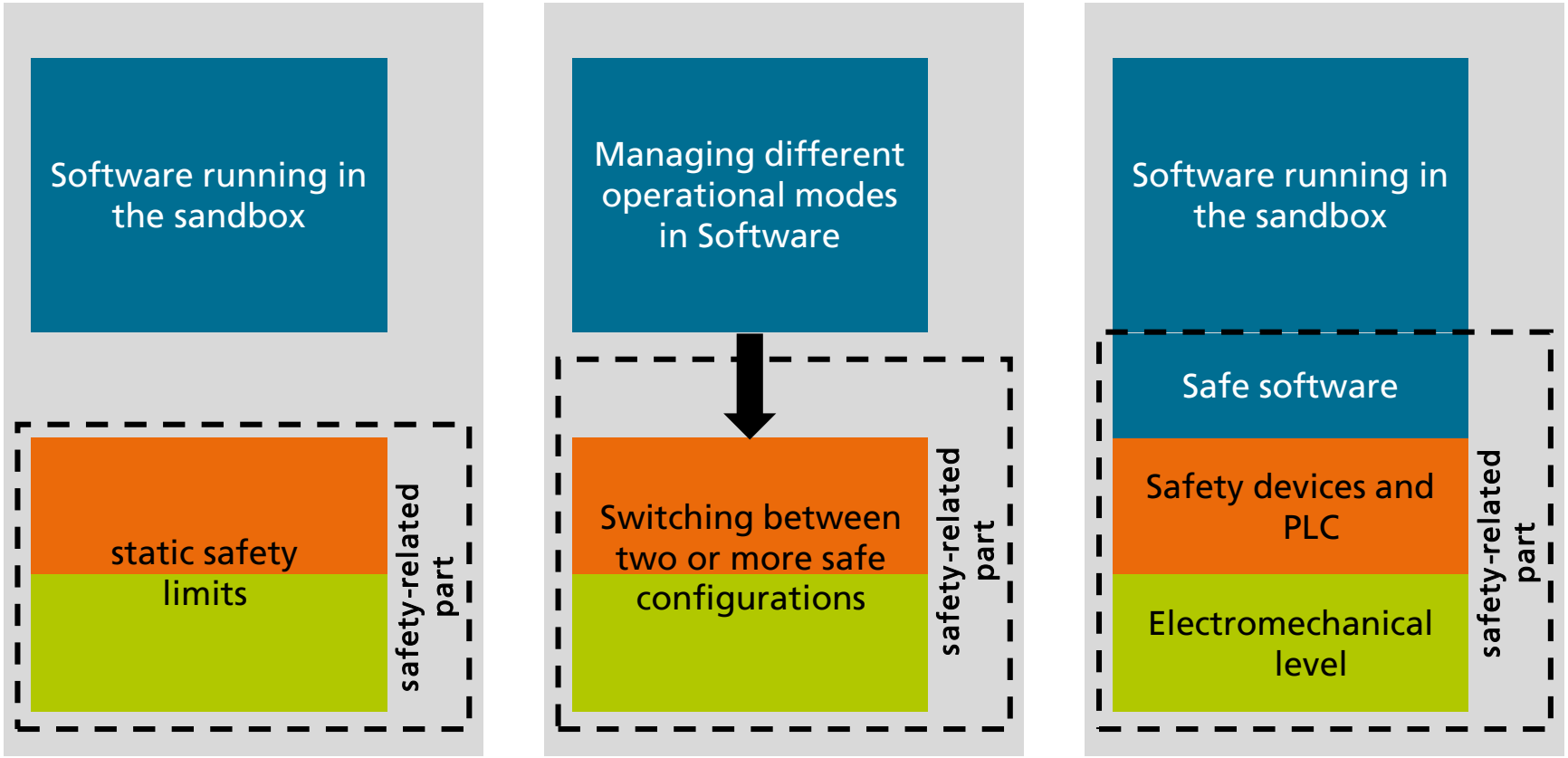
Safe software: Extending the boundaries of the safety-related control system



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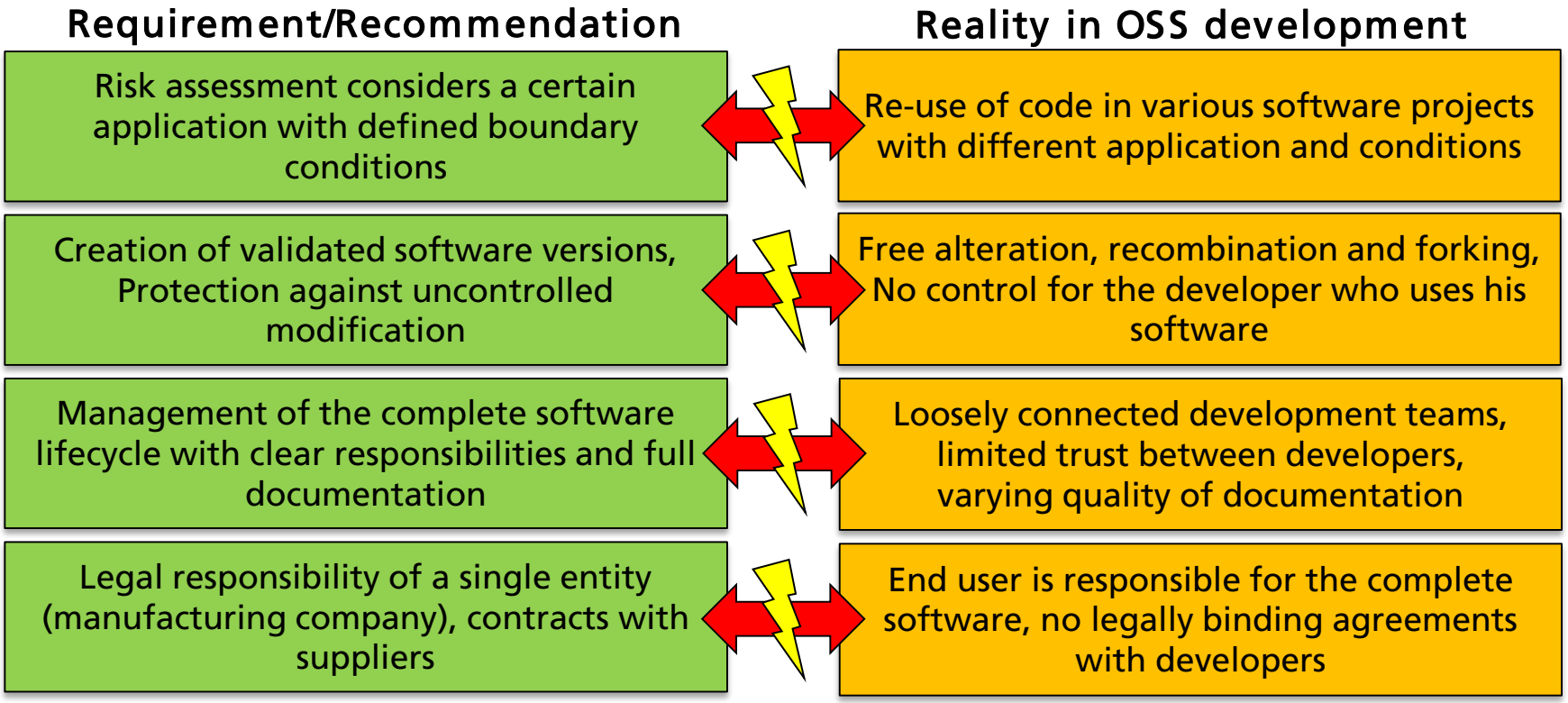
Requirements for designing and writing safe software – Organisational structures

- Applicable standards: IEC 62061 and IEC 61508-3 – Functional safety of electrical/electronic/ programmable electronic safety-related systems – Part 3: Software requirements
- Inclusion of software and computer hardware into the risk assessment process; determination of required control system performance (SIL)
  - Performance and reaction times need to be guaranteed
  - Clear separation between safety-related and other parts
- Management of the complete software lifecycle
  - Specification, Development, Validation, Use, Modification
  - Complete documentation of all processes
  - Definition of a detailed validation plan before the development starts
  - Determination of responsible persons for each process step
- Thorough validation at each level of the V-Model and repeated validation of affected parts after any modification

Requirements for designing and writing safe software – Code development

- Implementation of integrity checks at runtime-level
  - Cyclic self-tests of software and hardware integrity
  - For higher SILs: Redundant and diverse data processing
- Recommendation of methods and restrictions for the software development and validation process, e.g.
  - Use of well-established programming languages, where possible with a certified compiler
  - Avoiding error-prone code features such as dynamic objects, pointers, automatic type-conversions, etc.
  - Use of style-guidelines and structured programming methodologies
  - Architectures where process software and integrity checks run independent from each other

Possible conflicts between open source software and requirements for safe software



Conclusion: Possibly only works for

- Self-contained modules maintained by a small group of programmers
- Verified software versions with change-on-your-own-risk policies

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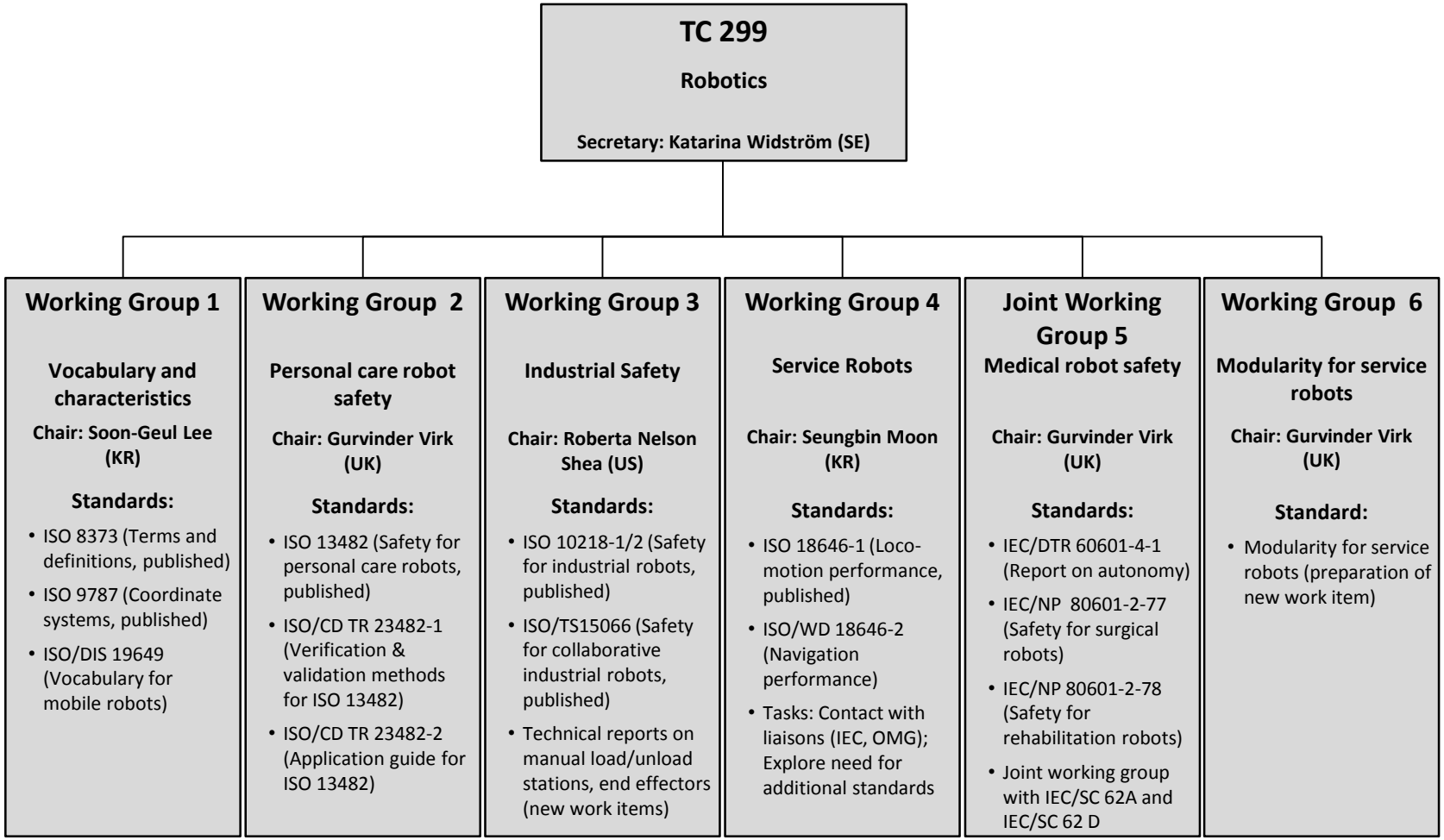
ISO Standardisation committee TC 299



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Standard development in ISO TC 299

- Working groups meet three times a year at changing locations (US, Europe, Asia)
- Instruments for developing a standard
  - Commenting – national experts propose changes in the document through comments
  - Homework – a small group of experts (e.g. one country) introduces new text
  - Balloting – official voting before a draft enters the next development step
- Countries currently contributing to the meetings: Canada, China, France, Germany, Japan, South Korea, Netherlands, Sweden, Switzerland, UK, USA
- Funding for travel costs for interested experts provided by FP7-Project RockEU 2
  - Goal: Ensure participation of European experts in sufficient strength
  - Reimbursement of travel costs and accommodation during a meeting
- Next meetings:
  - All WGs: November 7th to 18th in Orlando, Florida, United States
  - WG 1, 2, 4, 5, 6: February 6th to 17th 2017 in Daegu, South Korea

Conclusion

- Safety regulation for robots
  - Mandatory European directives on product safety
  - Extended by various harmonized standards
- Safe software:
  - Currently often excluded from safety-related part of the control system
  - IEC 61508-family specifies requirements for management, development and validation of code
  - Possible conflicts between safety requirements an principles of open source software
- Standardisation as a living process:
  - Continuously development and alteration of robot-related standards
  - Possibility to become a part of the standardisation process