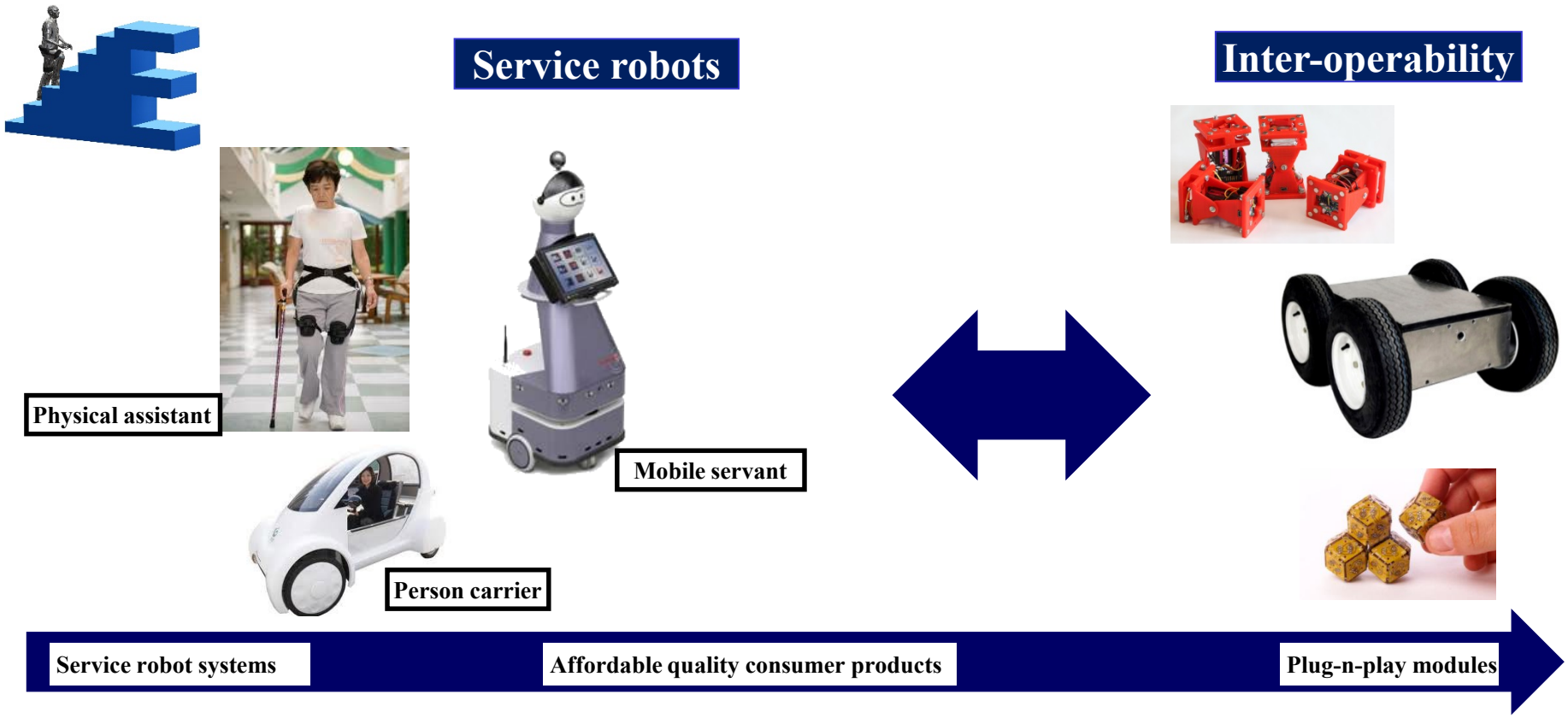


Modularity for service robots

Professor Gurvinder Singh Virk

Chairman/ MD, Endoenergy, UK & India; gsvirk@endoenergy.com
Trustee, CLAWAR Association Ltd, UK; gsvirk@clawar.org

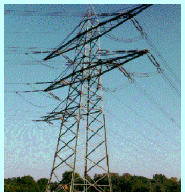
1) Convener: ISO TC 299/WG2: Personal care robot safety (2006 -2016)
2) Convener: IEC SC62A & ISO TC 299 JWG9: Medical robot safety (2011-2018)
3) Convener: ISO TC 299/WG6: Modularity for service robots (2014-Present)
4) Convenor: ISO TC 299/SG1: Gaps and structure (2017)
5) Director: euRobotics Topic Group Standardisation for H2020 (2014-2019)

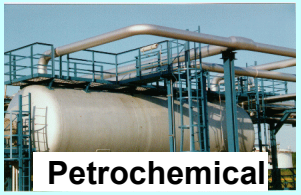
Summary of presentation

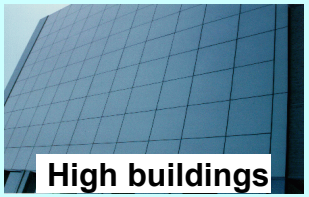
- **Changing world of robotics**
  - **Industrial ⇨ Service ⇨ Modularity**
- **Modularity for service robots: ISO 22166-1**
  - **Part 1: General requirements**
    - **Definitions**
    - **General principles**
    - **Safety and security**
    - **Hardware and software modularity**
  - **Family of standards**
- **Conclusions**

Changing world of robotics

- **Robots for hazardous environments: Hazardous environments**


Power lines


Petrochemical


High buildings

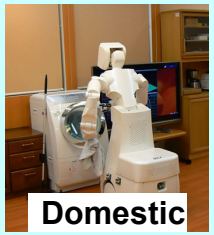

Oil tanks


Power stations

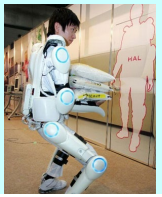

De-mining

- **Service robots: Useful tasks (close human-robot collaboration)**


Garbage


Domestic

Servant


Assistance

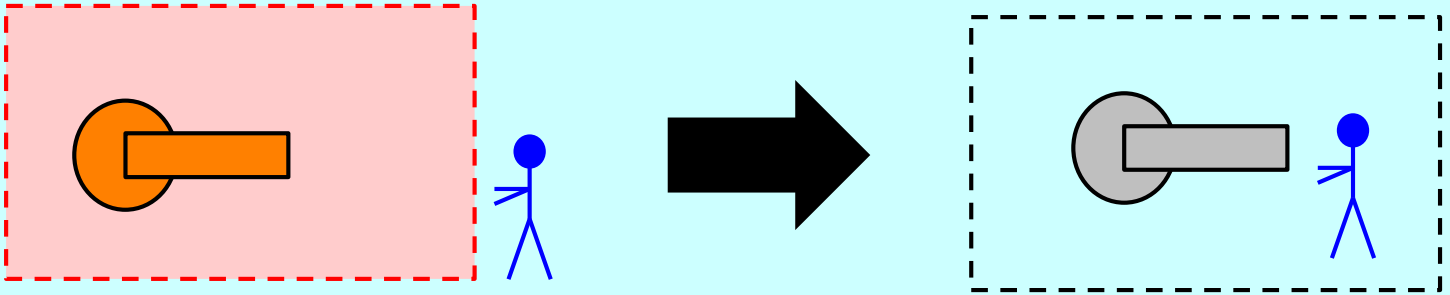

Person carrier


Rehabilitation

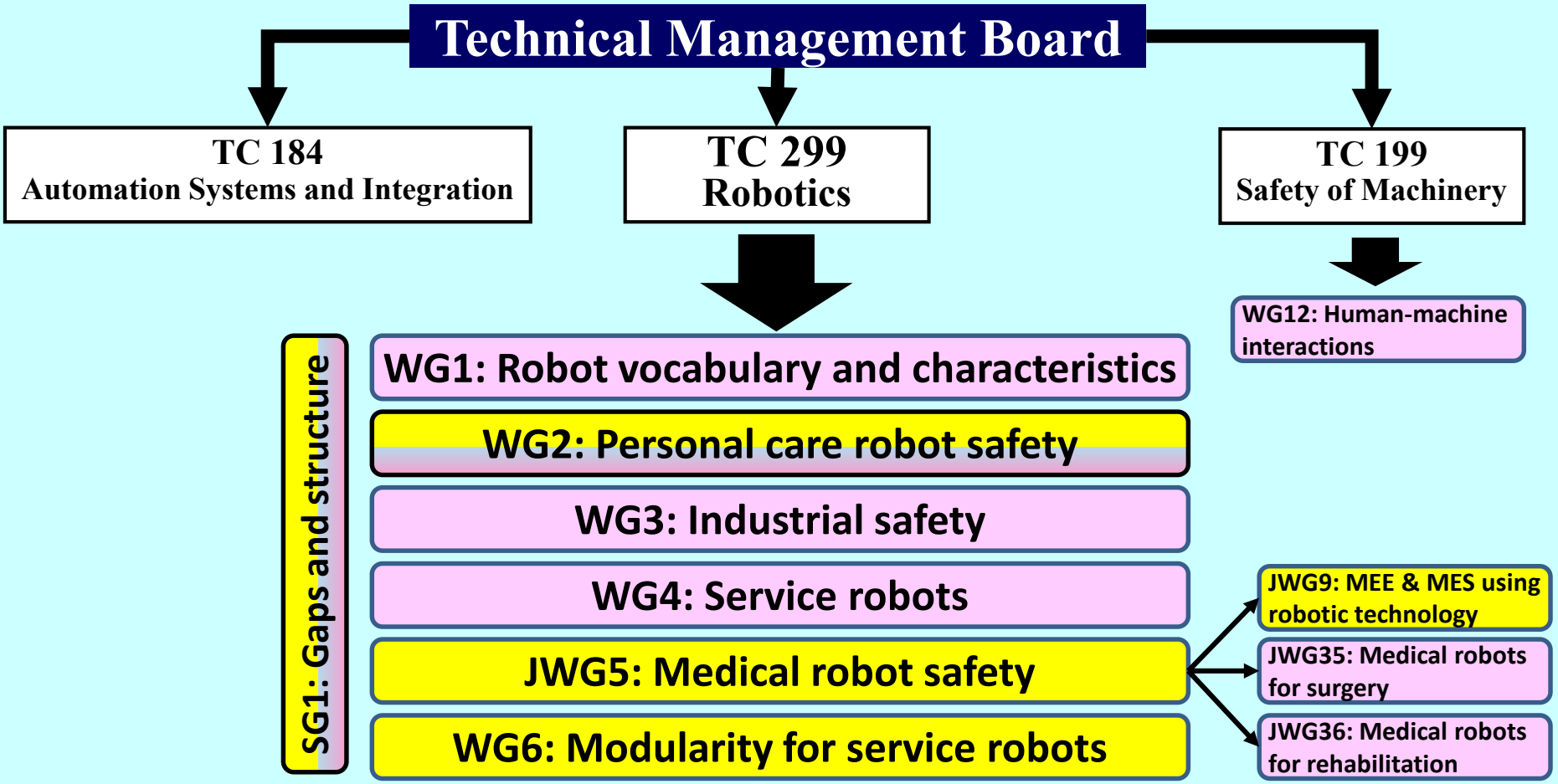

Surgery

Medical robots

- **Even industrial robots moving towards collaborative applications**



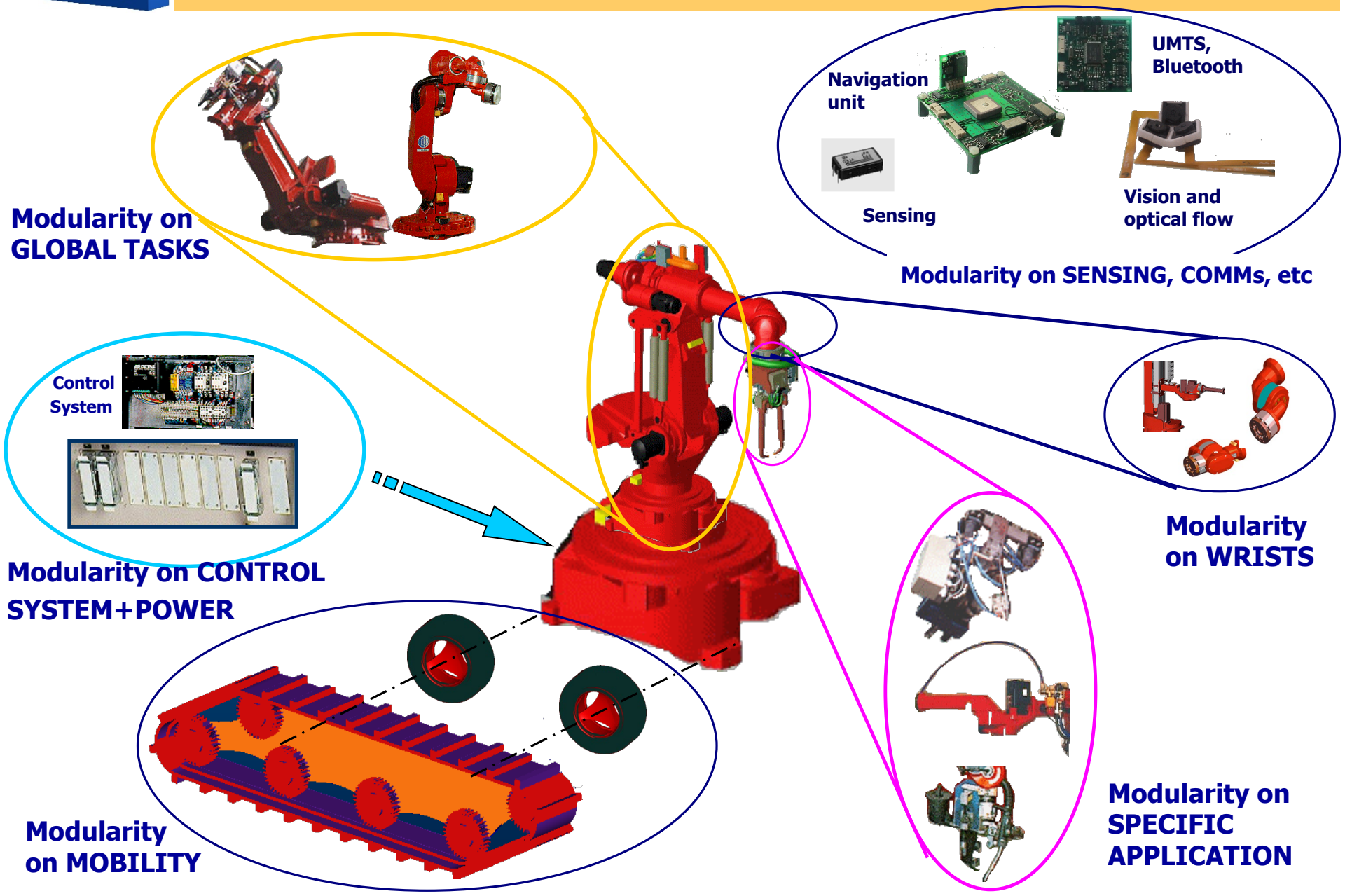
From Jan 2016: ISO TC 299 Robotics



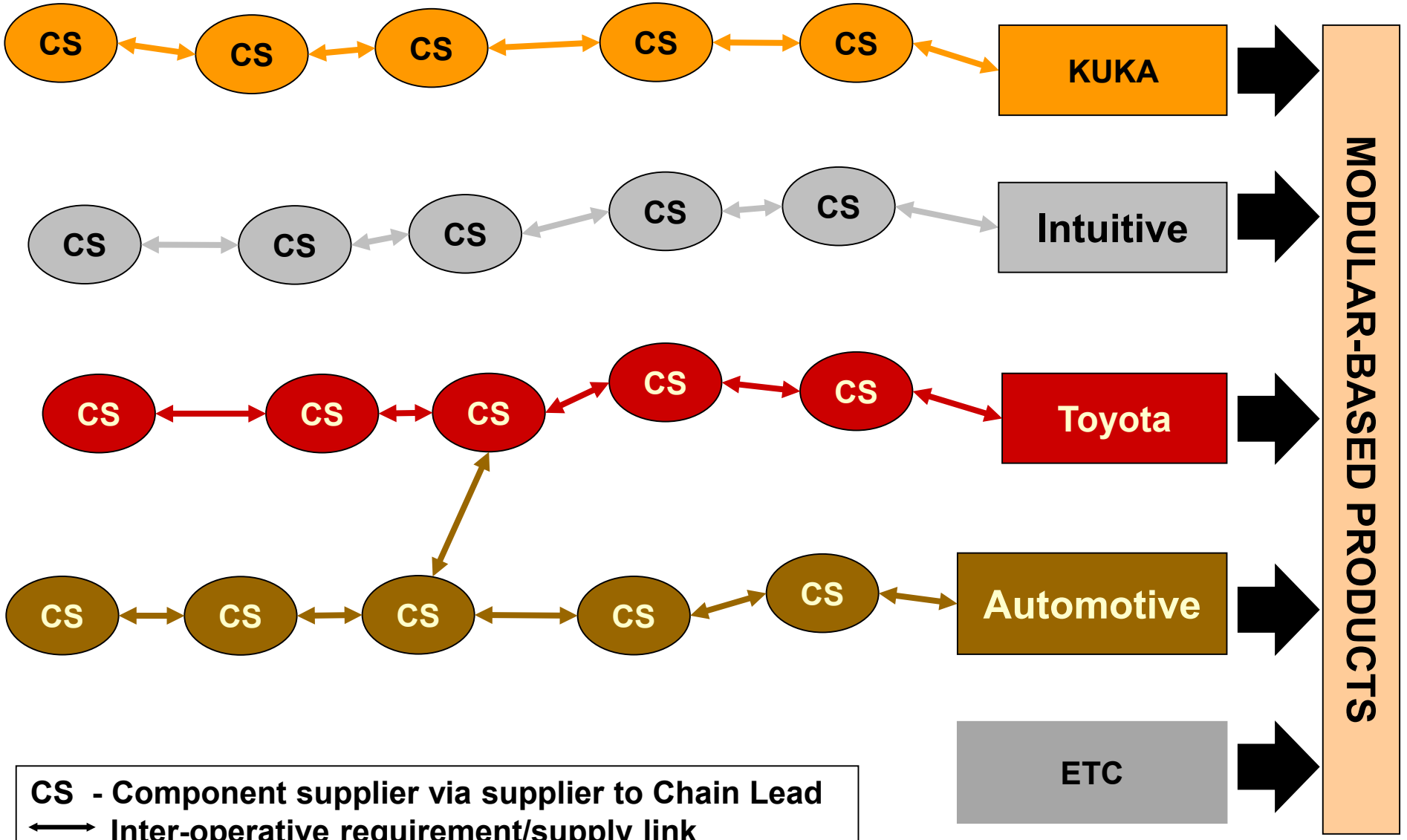
- ISO 8373:2012, Robot vocabulary
- ISO 10218-1:2011, Safety requirements for industrial robots: Robot
- ISO 10218-2:2011, Robot systems and integration
- ISO 13482:2014, Safety requirements for personal care robots
- ISO TS 15066:2016, Collaborative (industrial) robots
- ISO 18646-1:2016, Performance service robots – locomotion wheeled
- IEC TR 60601-4-1, MEE with DOA

- WG1: ISO CD 19649, Vocabulary for mobile robots
- WG2: Safety-related test methods for 13482 (ISO/TR 23482-1); App guide to 13482 (ISO /TR 23482-2),
- WG3: End effectors (ISO /DTR 20218-1); Manual load stations (Part 2)
- WG4: ISO 18646-2: CD on Navigation
- WG5: IEC 80601-2-77, BS&EP Med robots for surgery; IEC 80601-2-78, BS&EP Med robots for rehab
- WG6: ISO CD 22166-1 Modularity for service robots

Concepts for robot modularity



Traditional (closed) supply chains



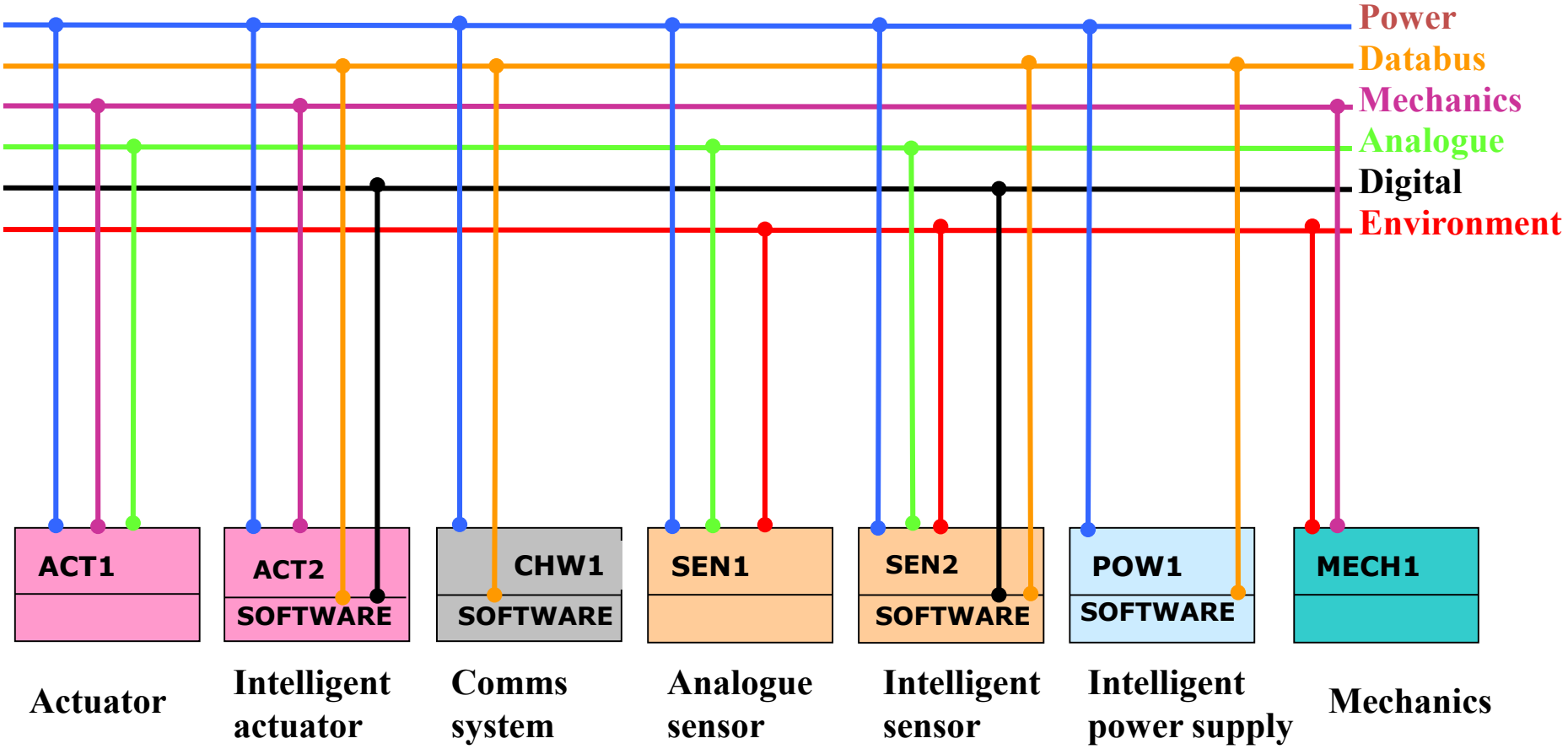
CS - Component supplier via supplier to Chain Lead
⟷ Inter-operative requirement/supply link

Modularity R&D state of the art

- Many concepts and designs developed based on simple identical interconnecting modules
- Excellent approaches and results achieved
- Able to build and demonstrate the reconfigurability of modular robots
- http://spectrum.ieee.org/automaton/robotics/diy/fable-modular-robotics
- Approaches have not been widely adopted due to being too "individualist"

CLAWAR modular design (≈40 organisations)

"Interaction Space": Generic design of robot modules (2001)



Interaction variables are: 1) Power; 2) Communications (global or direct point-to-point in analogue or digital forms), 3) Mechanical linkages, environmental aspects)

Why modularity standardisation?

- **Basic principles aims**
  - **Inter-changebility in an open way at the interface ("open wires and closed boxes")**
  - **Improve the cost-efficiency balance**
  - **Enhance rather than re-invent (H/W and S/W)**
- **Design/purchase/assemble rather than Design/prototyping**
- **Allow needed safety integrity to be achieved**
- **Application oriented**
  - **Scalable with functions easily increased or decreased**
  - **Different "Grade" modules/ components (Industrial, domestic, consumer, medical, etc.)**

ISO TC299/WG6: Modularity for service robots (CLAWAR leading)

WG6: Modularity for service robots

- **Convenor: Gurvinder S Virk, CLAWAR, UK; gsvirk@clawar.org**
- **Scope: Formulate robot modularity guidelines for inter-operability from hardware and software perspectives**
- **Current work: ISO CD 22166-1 Modularity for service robots – Part 1 – General requirements**
- **Main sections:**
  - **Terminology**
  - **General guidelines**
  - **Performance requirements for safety and security**
  - **Hardware aspects in module design**
  - **Software aspects in module design**
  - **Use case examples**
  - **Test methods**

Initial WG06 definitions

- **component:** part of something that is discrete and identifiable with respect to combining with other parts to produce something larger
- **module:** component or assembly of components with a defined interfaces accompanied with property profile to facilitate system design, integration, interoperability, and re-use
- **hardware module:** module whose implementation consists purely of physical parts, including mechanical parts, electronic circuits and any software, such as firmware, not externally accessible through any communication interface
- **software module:** module whose implementation consists purely of programmed algorithms
- **robot module:** module intended to be used as part of a modular robot system
- **interoperability:** capability to communicate, execute programs or transfer data or power among modules or combine modules physically and/or logically in a manner that requires the user to have little or no knowledge of the unique characteristics of the individual modules
- **interface:** shared boundary between two or more functional modules, defined by various characteristics pertaining to the functions, signal exchanges, and other characteristics
- **modularity:** characteristic which allow systems to be separated into discrete modules and recombined

WG6 General principles for modularity

1. **Composibility: ability to assemble modules logically and physically using various combinations into new composite modules for performing more sophisticated operations**
2. **Integrability: Integrability is the process of integrating together all aspects of the modules (both hardware and software aspects) to form larger systems**
3. **Interoperability: increasingly important as defined for modularisation, especially within IT**
4. **Granularity: degree to which a module can be broken down into separate modules**
5. **Platform independence: technology whereby modules can be implemented on one service robot or one set of modules and be used on another robot or with another set of modules without significant modification**
6. **Openness: concept characterized by several ideals such as transparency, free and unrestricted access to information when appropriate, and by full sharing of relevant information**
7. **Reusability: by defining appropriate interfaces such as software interfaces, electrical connectors between modules, and linkages between hardware aspects of modules**
8. **Safety: process by which modules and the overall robot system operate with acceptable risk under a single fault condition and are furthermore designed to remain in the condition of being free from errors, failures and hazards**
9. **Security: ensuring that the modules are resistant to attempts to access or tamper with them by unauthorised methods or persons**

Robot Module Template

Module name: ***A natural language name of a specific module or class of modules***
Description: *Overview of module, what the module is, what it does and how it can be used*
Manufacturer: *Contact information for the developer(s) of the module. This can include details of the designer, the manufacturer, or the vendor organisations.*
Module ID: *Manufacturer's unique product reference number for module*
Examples: *Typical use case examples of the module*
Hardware aspects: *Summary details regarding hardware aspects, see Clause 6 (via examples if possible)*
Software aspects: *Summary details regarding software aspects, see Clause 7 (via examples if possible)*
Properties: *List of module properties (see Clauses 6 and 7)*
Inputs: *List of module inputs*
Outputs: *List of module outputs*
Function/Functionality: *A description of the way that the module accepts inputs, processes them to determine its outputs. The use of suitable diagrams (using for example the line, circle or SysML methods presented in this standard) to illustrate the functionality is recommended.*
Infrastructure: *The type of infrastructure support and/or the environmental protection provided (e.g., power lines, data lines, database management system, safety bus, IP protection, enterprise resource planning, supply chain management, etc)*
Safety: *Safety related requirements for module level and system level safety (e.g., to meet required performance levels)*
Security: *Security requirements for unauthorised access and guarantee appropriate level of privacy*
Modelling: *Mathematical or physical description of module applied to various test scenarios (e.g virtual module model)*

Performance for safety and security

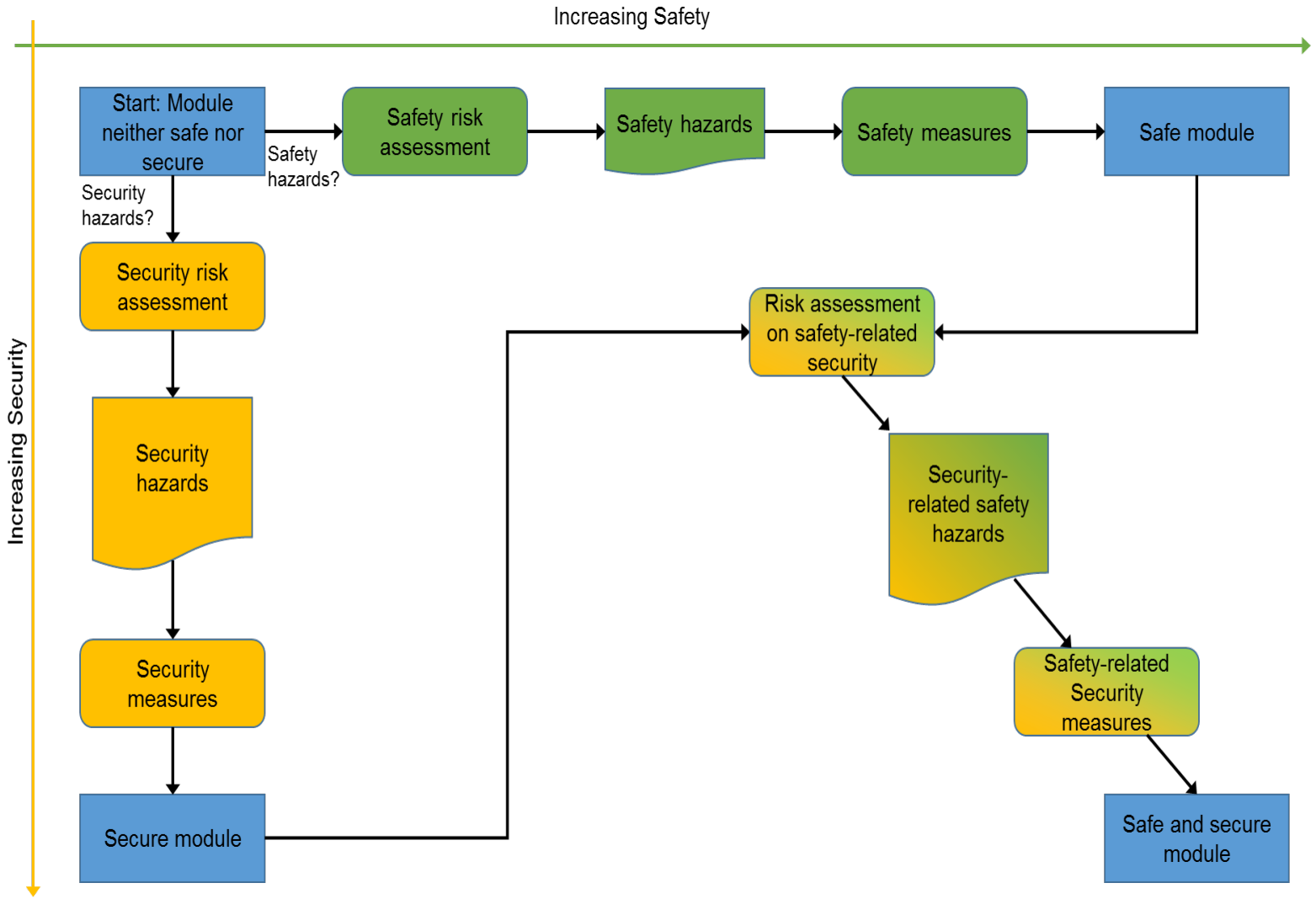
Safety

- **Steps to define safety level of modules:**
  1. Define the intended use cases for using the module
  2. With the defined use cases hypothetical robot system design should be carried out where the module is expected to be deployed
  3. The assumption that the system has a safety supervisor can be made
  4. The required PL for the module should be defined based on the application based intended use cases
  5. Appropriate PL shall be defined for relevant safety related functions in the module. Consider a local safety rated function in the module to take care of this functionality Please refer to the safety supervisor in clause 7.2
  6. The safety functions assumed and their required PLs that need to be taken in account by the safety supervisor

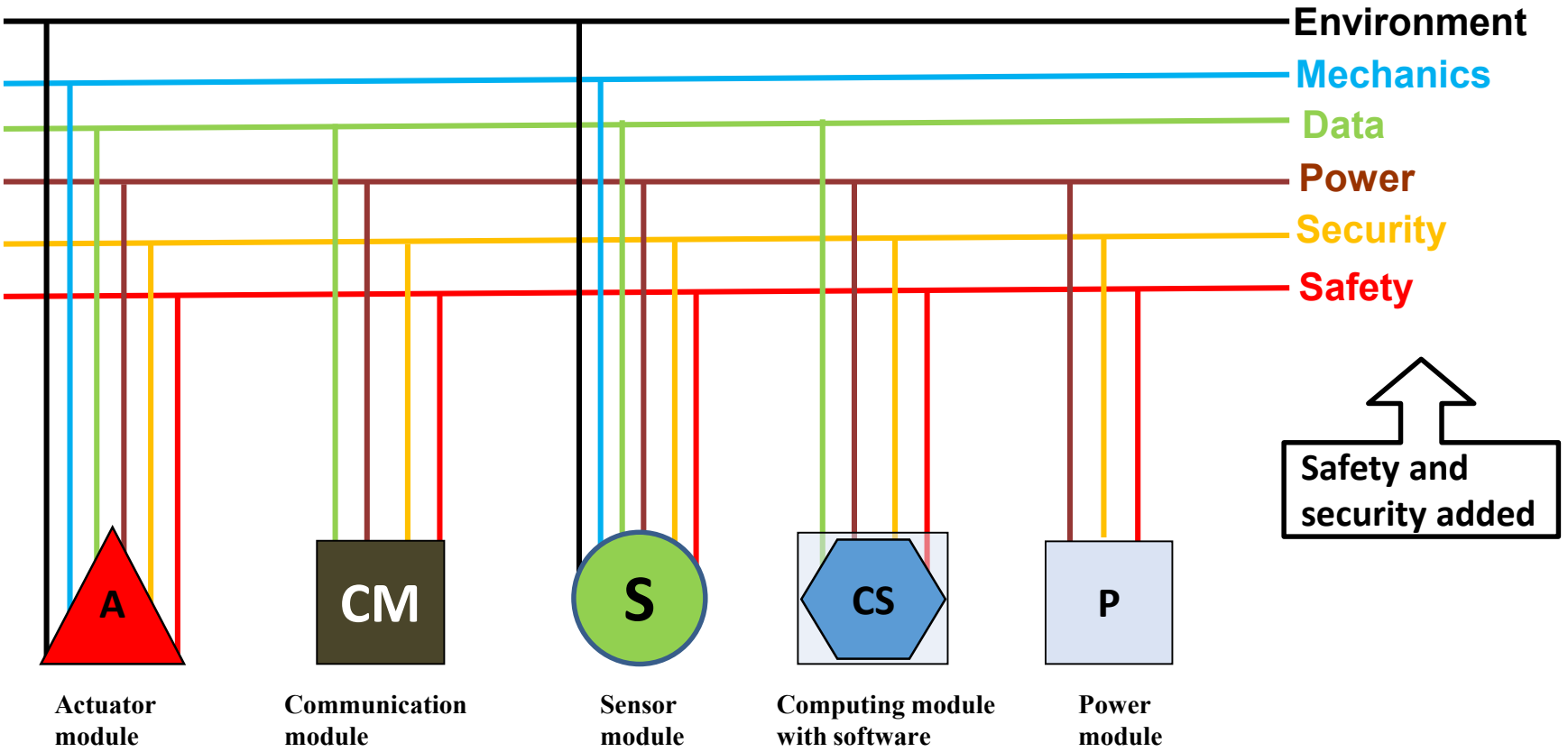
Security

- **Modular level security shall ensure the modules are resistant to unauthorized access**
- **Levels of security defined:**
  - Type 0: No security lock and sensor (no security is required)
  - Type 1: Latch sensor (no security is required but need to know if in open or closed state)
  - Type 2: Mechanical lock with a physical key
  - Type 3: Mechanical lock with a latch actuator
  - Type 4: Combination of type 1 to 3
- **Cyber security risk assessment and risk reduction should consider:**
  - Confidentiality
  - Integrity
  - Availability

Safety and security risk assessment process for robot modules



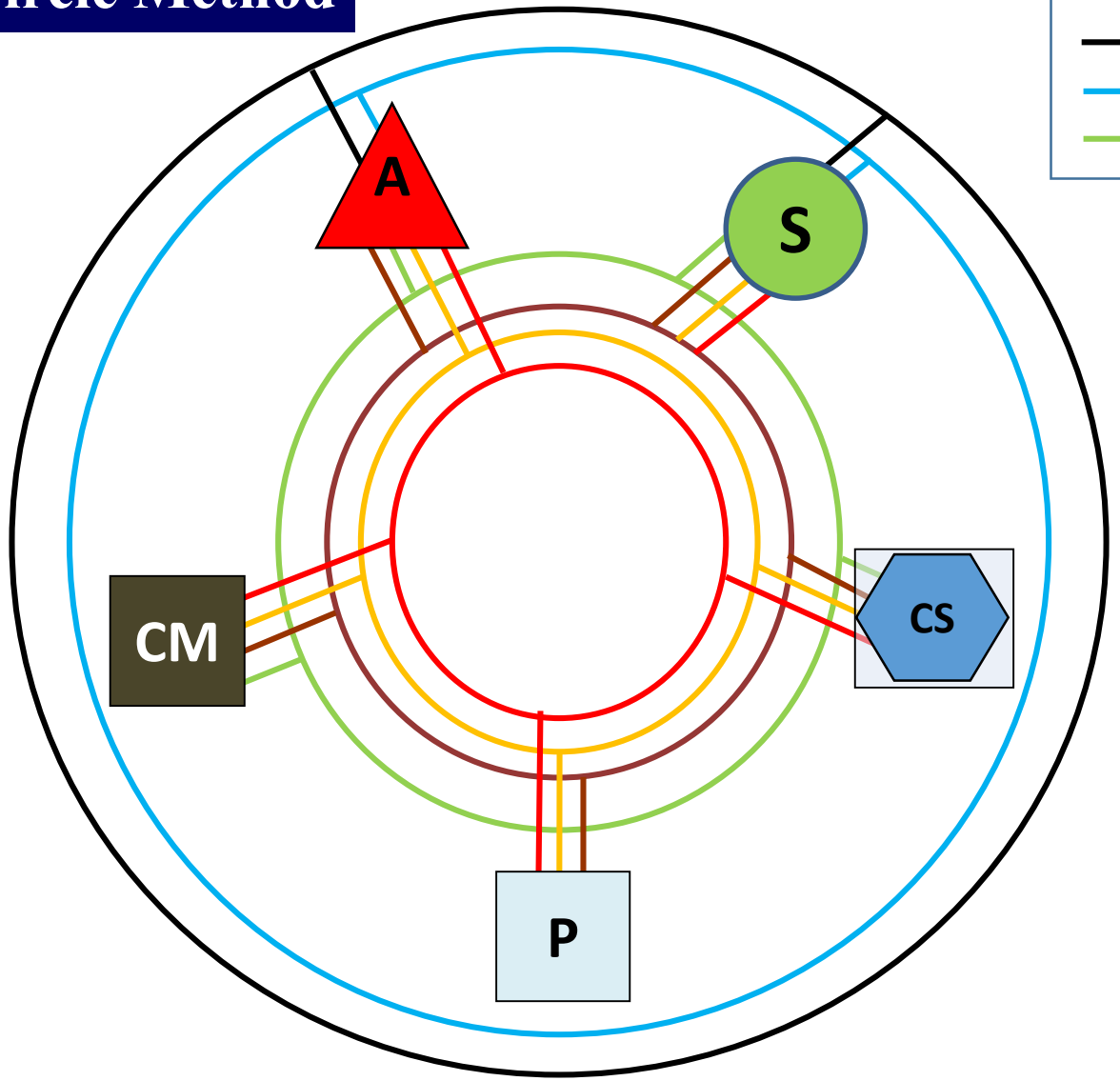
WG06 Modularity connectivity framework 1



Line Method

WG06 Modularity connectivity framework 2

Circle Method



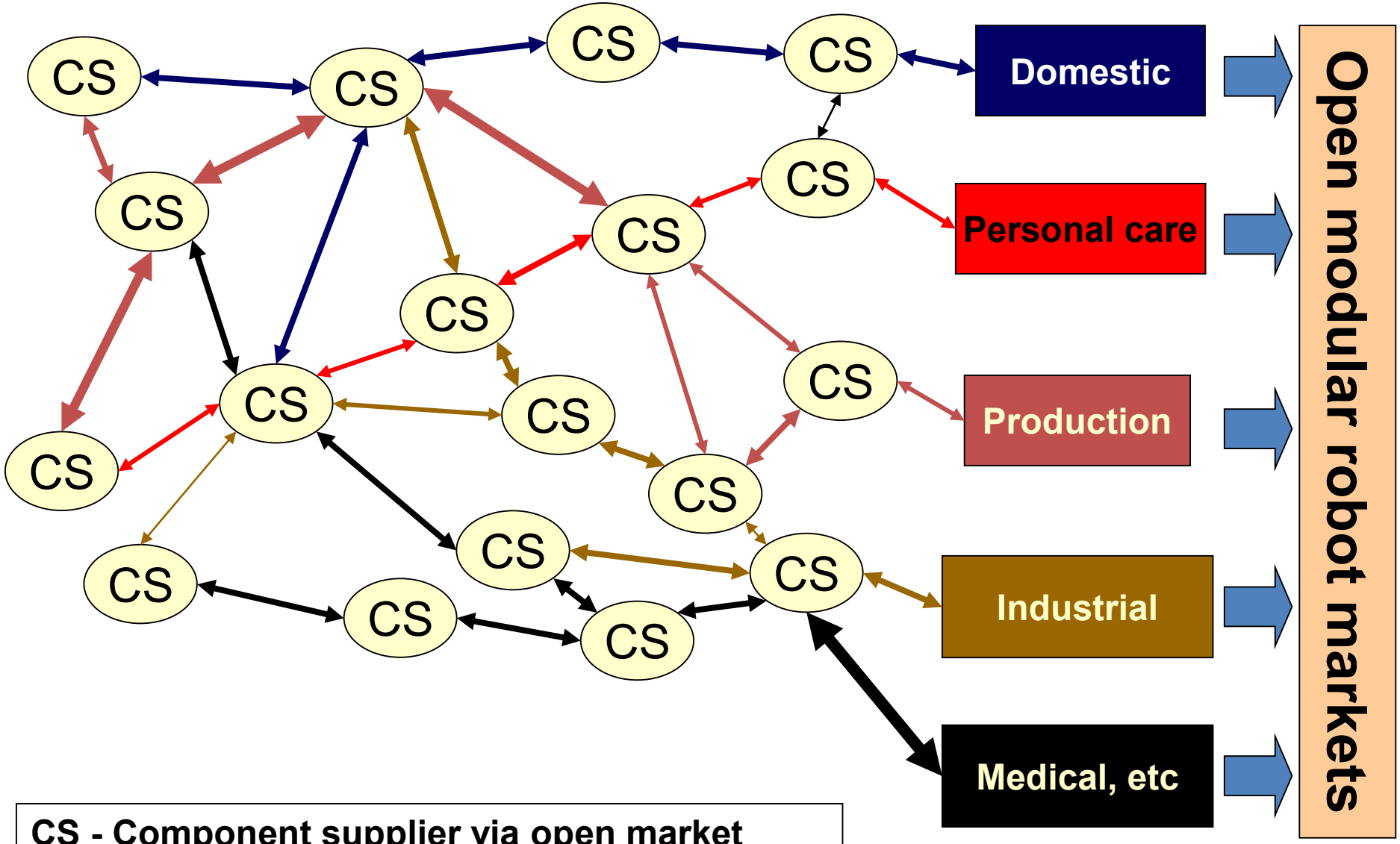
Interfacing connections

- Environment
- Mechanics
- Data
- Power
- Security
- Safety

Modules

- Sensor (S)
- Software (SW)
- Actuator (A)
- Power supply (PS)
- Communication (CM)
- Computing module with software (CS)

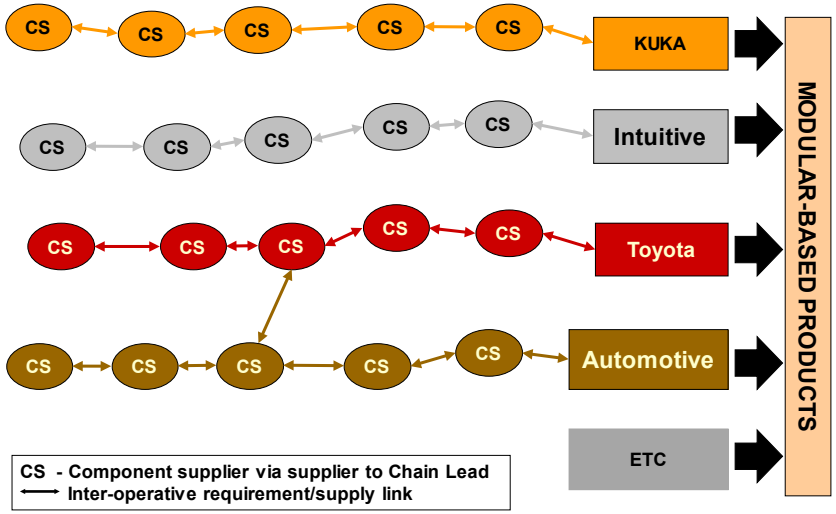
Modularity (open) chain markets



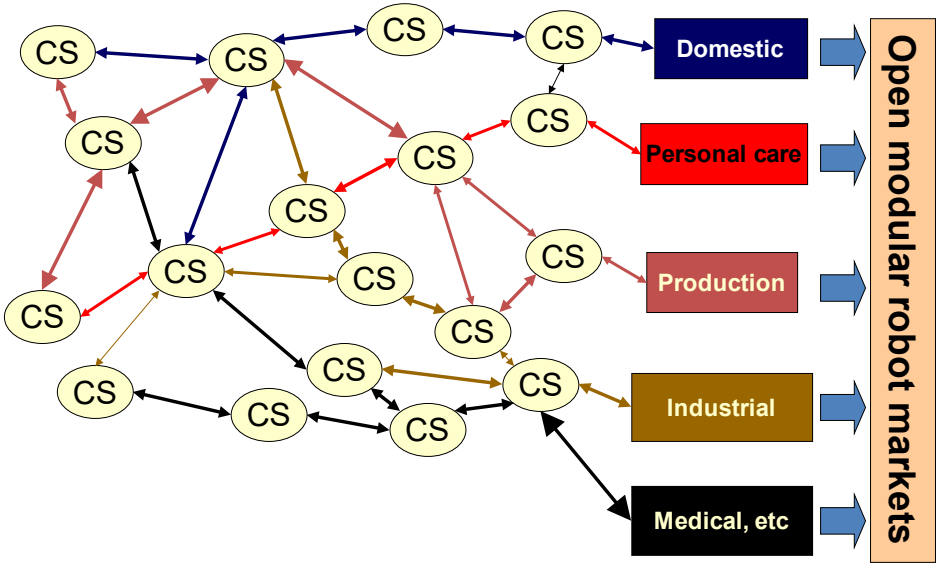
CS - Component supplier via open market

⟷ - Inter-operative requirement/supply link

Missing demonstrations



Conventional dedicated (closed) supply chain set up and operated by large organisations/ consortiums



Set up and demonstration of new open supply chains and operated for key applications robot sectors

ISO 22166 Family of standards

- **ISO 22166-1, Modularity for service robots – Part 1: General requirements**
- **ISO 22166-2, Interfaces. Hongseong Park, South Korea leading**
- **ISO 22166-3, Common modules. Anson Lee, China leading**
- **Modularity for medical robots. Jointly with IEC TC62. Gurvinder S Virk leading.**

Conclusions

- Robotics is moving to new service sectors where demands are wider from traditional industrial environments especially safety for medical and non-medical sectors
- Modularity is key to delivering the technologies and systems needed at an affordable cost
- CLAWAR's work on modularity (2001) is being extended to realize a generic approach for specifying ISO requirements for service robot modularity
- IP in the "boxes" not the "wires"(H/W & S/W) to specify inter-operability standards for plug-n-play modules including safety and security considerations
- Researchers should align to international directions and support required technology innovations needed

End

Thank you for your kind attention

Professor Gurvinder Singh Virk
Chairman/ MD, Endoenergy, UK & India; gsvirk@endoenergy.com
Trustee, CLAWAR Association Ltd, UK; gsvirk@clawar.org