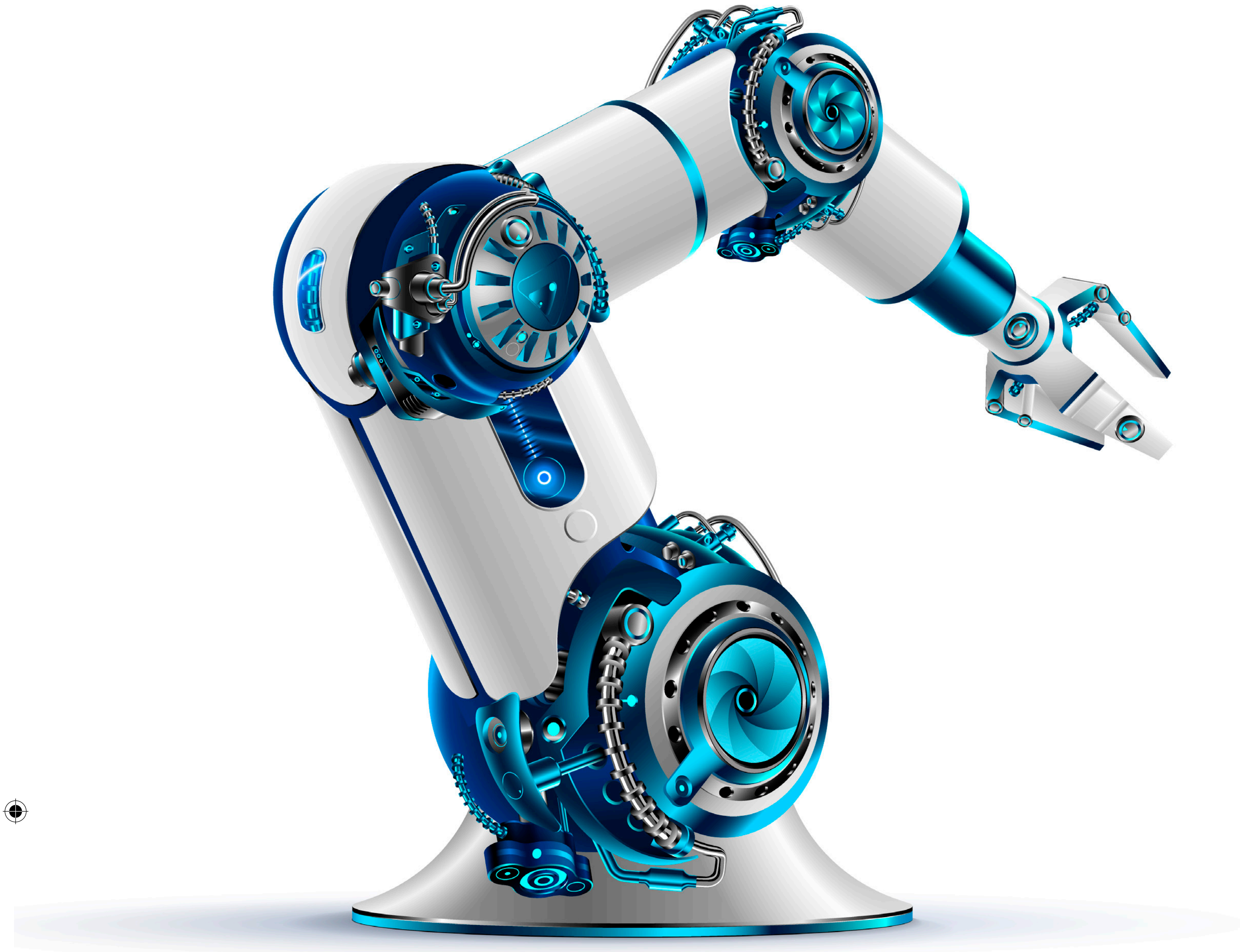

Human-systems integration for the effective implementation of automation

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In addition to improving productivity, increased automation has considerable potential to reduce safety and health risks by removing people from hazardous situations. Automation, however, does not remove people from the system – it just changes the tasks that they undertake. For the system to function safely and effectively, these new tasks must be designed with human abilities and limitations taken into account.

The choice of which functions should be automated requires consideration of the capabilities and limitations of humans. People are good at perceiving patterns; they adapt, improvise and accommodate quickly to unexpected variability. People are not good at precise repetition of actions or vigilant tasks. System design requires more than allocating functions to person and machine; rather, the challenge is to identify how the operators, supervisors, maintainers and automated components can collaborate effectively to perform the functions required. The impact of automation on current and potential future employees also requires examination to ensure that the change is managed for optimal safety and health outcomes.

These objectives may be achieved through using human-systems integration (HSI) processes during system design and introduction. HSI refers to a set of systems engineering processes, originally developed by the US defence industry, to ensure that human-related issues are adequately considered during system planning, design, development and evaluation.

> "HSI is a continuous process that should begin during the definition of requirements for any automation project, continue throughout system design, and throughout commissioning and operation in order to verify that safety goals have been achieved"

There are six core domains of HSI that are relevant to the introduction of automation in the resources sector:

1. staffing
2. personnel
3. training
4. human-factors engineering
5. safety
6. occupational health.

Staffing relates to decisions regarding the number, and characteristics, of roles that will be required to operate and maintain the joint human-automation system.

The personnel and training domains concern, respectively, the related issues of the characteristics of the personnel who will be selected to fill those roles; the extent and methods of training; the competency assessment involved in preparing personnel to obtain and maintain the competencies required for safe operation; and the maintenance of the joint human-automation system.

Rather than being decreased, training requirements for operators interacting with highly autonomous systems are likely to be increased to ensure that the operation of the automation is fully understood. For example, automated-system controllers need to understand system hazards and logic, the reasons behind safety-critical procedures, potential results of overriding controls, and how to interpret feedback. Skills for solving problems and dealing with unanticipated events are also required, while emergency procedures must be over-learned and frequently practiced.

The design of training should encompass a structured process, incorporating a training-needs analysis, leading to the definition of the functional specifications; an iterative design component incorporating usability testing; and evaluation. The use of simulation is a promising method for allowing trainees to be exposed to rare events, and for competency assessment.

Human-factors engineering encompasses the consideration of human capabilities and limitations in system design, development, and evaluation. In the automation context, this is particularly important in the design of interfaces between people and automated components. Methods employed in human-factors engineering include task analyses and human performance measures (e.g. workload, usability and situation awareness), as well as participatory human-centred design techniques.

The safety domain includes the consideration of the safety risks – such as those addressed in ISO 17757:2017 – that are associated with autonomous earthmoving equipment and mining machines, and that are outlined in the Department of Mines and Petroleum's Safe Mobile Autonomous Mining in Western Australia Code Of Practice. Relevant methods include traditional risk analysis and evaluation techniques, such as hazard and operability studies (HAZOP), layers of protection analysis (LOPA), failure modes and effects analysis (FMEA), and functional safety analyses and systems-theoretic process analysis (STPA).

STPA, in particular, may be useful for the analysis of complex systems involving automated components, because both software and human operators are included in the analysis. STPA is a proactive analysis method that identifies potential unsafe conditions during development, and avoids the simplistic linear causality assumptions inherent in HAZOP, LOPA and FMEA. Safety is treated as a control problem, rather than a failure prevention problem, and unsafe conditions are viewed as a consequence of complex dynamic processes that may operate concurrently. STPA also includes consideration of the wider dynamic and organisational context in which the automated system is situated.

The health domain encompasses the use of risk-management techniques, and task-based risk assessment in particular, to ensure that the system design minimises the risks of adverse health consequences to system operators and maintainers, and, indeed, anyone else potentially impacted by the system activities. These analyses should encompass all operational and maintenance activities associated with the autonomous component or system.

One health issue associated with the introduction of autonomous systems to mines and quarries is the potential impact on the mental health of control room operators tasked with interacting with autonomous systems. Stress associated with high or low cognitive workloads, potentially combined with reduced social interactions and low control of workload, and/or production pressures, may lead to adverse mental health consequences.

An overall focus on HSI includes consideration of interactions and potential trade-offs between decisions made in different domains. For example, decisions regarding automation and interface complexity may influence personnel characteristics and training requirements, as well as the anticipated number of people required for system operation and maintenance.

Systems engineering involves three stages: analysis, design and development, and testing and evaluation. HSI incorporates human-centred analysis, design and evaluation within the broader systems-engineering process. That is, HSI is a continuous process that should begin during the definition of requirements for any automation project, continue throughout system design, and throughout commissioning and operation in order to verify that safety goals have been achieved. Of course, a complete system safety program must extend beyond the system design and commissioning, and continue for the entire life of the system. AR&I