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Ambiguous terminology for advanced control systems can impact the perception of risk

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Abstract

Experts and practitioners in the chemical industry need to know how technology works and require the ability to explain it to the end user. Modern or new technology which is used to control high-hazard chemical processes, for example, real-time flowsheet optimization and control under uncertainty; or dynamic predictive control systems, require the same level of comprehension and understanding as older more traditional technology which is described in section 1.2. This is essential to avoid misinterpretation of hazards and risks. If terminology is transparent, then industry practitioners can be intelligent customers when procuring new technology.

For a long time, industry has used the term Advanced Control Systems (ACS) to describe new technology, this causes confusion as technology has developed over the decades. We aim to assess if this confusion in terminology has an impact on the perception of risk associated with new technology being used to control high-hazard chemical processes.

A survey was conducted to explore experts' and practitioners' perceptions of terms used to describe automation and digitalisation versus their understanding of the ACS. 71% of experts and practitioners acknowledged there was a difference between the two terms. However, when asked to define each term from a list of options there was little agreement between participants. Technology vendors can exploit the lack of consensus in their marketing strategies. The paper also discusses the likely psychological impact of using certain terminology and using terms that have different technical meanings.

The resultant proposal focuses on the key properties of an ACS instead of specifying a set of technologies to the definition of ACS. Focusing on key properties provides insights into the ACS which will help us determine how to use it safely and appropriately. In conclusion, the terminology used to describe new technology leads to misconceptions. The extent of the misconceptions creating safety implications is difficult to quantify. This paper provides awareness of the issue.

1 Introduction

There is considerable interest by chemical production companies in "digitalisation and automation" technologies. Many of these involve changes to the technology used for control purposes, replacing traditional technologies, such as traditional hardwired closed control loops which comply with IEC 61511, with newer technologies using neural networks which are not easily understood. While it seems likely that these new technologies offer many advantages, particularly for production efficiency, it is not clear that traditional safety approaches will work adequately for them. In particular, the increased complexity of these new technologies (which we will henceforth call "advanced control systems" (ACS)) makes them harder to understand and thus it is harder to perform adequate safety analysis and design for safety.

The potential safety risks posed by advanced control systems are not always apparent from the way they are described by proponents and vendors. This is because the terminology used to describe new advanced control systems in industry is vague. This paper demonstrates a need for the terminology used in industry to be more specific when describing the new advanced control systems. We argue that this has the potential to affect the perception of risk of the new advanced control systems. The vendors of new advanced control systems/techniques label them as products which generate high efficiency and low overheads [1]. However, the new advanced control systems involve complexities which may be unknown to the end user and could introduce safety issues.

1.1 Background

It is not surprising that companies are looking to adopt new technologies. Globalisation has caused increased competition in process industries as a result new technologies are adopted to either remain competitive with peers, hold onto market share, or gain a competitive advantage [2]. From a global perspective, there is pressure on businesses to adapt to changes such as climate change, and the availability of raw materials including clean water. In addition, international supply chains bring added competitors to existing markets [1]. The main trends of market globalisation, competition and consumer demands set the pace at which industry responds.

Most businesses are dynamic and will seek out the most effective solutions to help them deal with changes in the marketplace. For process industries, the rate at which they can respond to a changing market is crucial to gaining a competitive edge. Product innovation and the rate of production play a key role in how process industries are able to respond to a changing market [3].

The methods used by the process industry to allow businesses the chance to be competitive are via two main avenues. Firstly, innovation of products (such as for example products and production finding the term cut costs simulations can help with R&D reformulation) is carried out via research and development. Secondly is to concentrate efforts on the actual manufacturing process and how to optimise it [4]. Both methods use digitalisation and automation as the route to stay competitive, and this is being made easier with the rapid development of technology.

In the context of digitalisation and automation, a common umbrella term used is "industry 4.0", which combines manual and automated roles in production to fully digitalised autonomous and smart production models. The type of evolution where a rapid uptake in new technology is defined [5] "as a new level of organization and control over the entire value chain of the life cycle of products; it is geared towards increasingly individualized customer requirements". A consistent gap in literature is the lack of understanding and knowledge surrounding the effects of the rapid transformations in technology types and their uptake in industry.

Many industries that have adopted process automation to improve their capacity to adapt to changes in market demands and requirements. As organisations focus on the success provided by automation at the forefront, they fail to consider the downside to having a digitalised process. Such as cyber security, capital, and infrastructure costs [6].

To explore the scale of the complexities associated with digitalisation and automation we consider only one sector of the process industry namely the chemical and petrochemical part. However, process industries include much of the manufacturing sector which spans many different industry sectors such as minerals, steel, metals, pulp, paper, pharmaceuticals, cosmetics, paint, soaps, cement, glass, food, and beverages. [1], [3], [4], [7], [8] The list of industries is not exhausted nevertheless it is an illustration into how large and wide the term process industry expands.

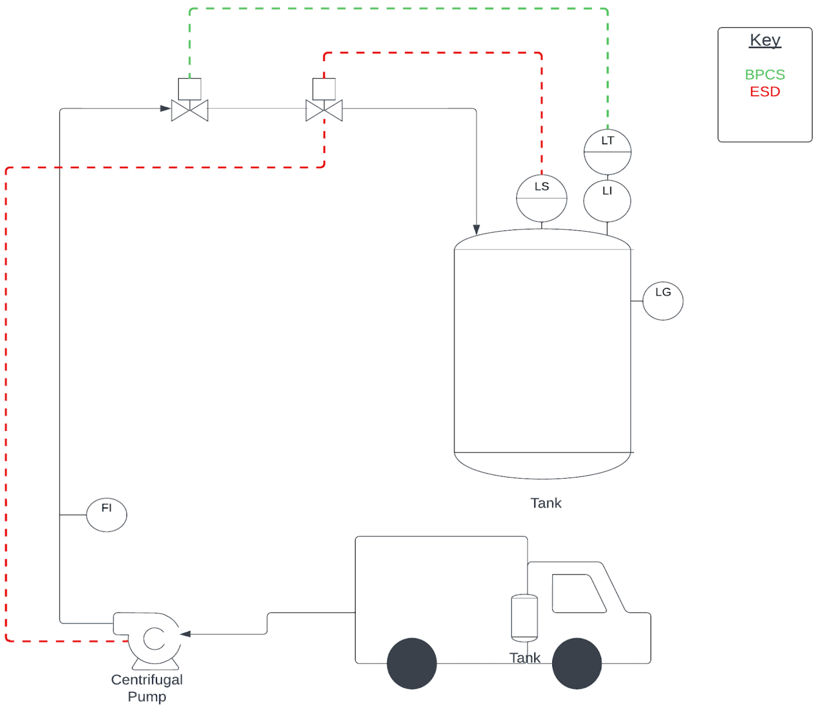
Section 2 and 3 of this paper describes the data collection and interpretation of the complexities caused by the rapid uptake of new technology with respect to uncertainty of terminology and discusses the potential impact on safety. Section 4 proposes a definition of ACS for the current market.

1.2 Most common control techniques used in the chemical industry

Before looking at the terminology used in industry, a clarification of technology types needs to be examined as this will help to explain how terminology is being misused and causing confusion. There is a differentiation between technologies traditionally used versus new technology used to control chemical plants and processes.

This paper uses the term "control technique" for engineered solutions put in place to stop an excursion from occurring, an excursion meaning the process goes beyond its normal mode of operation and can lead to a fire explosion and or toxic release. Traditionally the chemical industry uses two forms of control techniques. We will call the first a basic process control system (BPCS) which keeps the process within the designer's design limits. The second is a layer of protection which is separate from the BPCS and acts in an emergency, whether that be in the form of an emergency quench or activation of a recipe change. In this paper, we refer to this layer of protection as an emergency shutdown system (ESD). The ESD system is independently hardwired and what we described as the last line of defence. Refer to diagram 1. Quite often the ESD takes the form of a safety instrumented system (SIS) which complies with IEC 61511 and may be a safety-critical system. We will define a safety critical system as being identified through hazard and risk identification processes which requires a safety instrumented function (SIF) to ensure a major accident hazard is prevented from occurring. [9]

Diagram 1 explains both traditional ways to control a chemical process.



2 Key problems due to ambiguous terminology

The term "complex system" can easily be thought of as a large complex web or network. However, it is important to note that a system with a small number of steps or limited parts and relationships can also be complex [10], [11]. From a safety perspective, there is little evidence in research regarding the safety impact of advanced control on the wider environment of a system. Also, there is limited knowledge of unintended interactions from using advanced control techniques for high-hazard processes.

Therefore, a starting point to review current terminology begins with the chemical industry which is going through a digital transformation comparable to the concept of Industry 4.0. The definition of digital transformation previously quoted [12] is, "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies". This suggests the changeover to a digital world simply improves communication efficiencies. This is a good example of how terminology can direct perception and highlight the need for terminology used in industry to be more specific when describing the new advanced control systems.

Factory environments have changed to include various new technologies best described by Dotoli et al (2017) [13], "The term advanced control refers to a wide range of techniques applied in industrial plants and typically integrating tools from various disciplines – control systems engineering, signal processing, statistics, decision theory, and artificial intelligence." However, we need to take this definition and create more clarity, especially for non-computer scientists.

Much of the literature describes advanced control systems as a task-specific definition. For example, an advanced control system/technique for an aircraft or a specific plant/process. Therefore, it is unsurprising that this term has been used for many decades. However, due to the fundamentals of the technology change, it is essential to create a transparent definition of the term advanced control system/techniques for the 21st century.

3 Survey of experts to determine terminology uses

We carried out a survey with the aim of establishing an understanding of what experts and practitioners in the chemical industry believe when it comes to terminology surrounding the two commonly used terms "automation and digitalisation" and "ACS". In the process, the survey helped to assess their awareness of technology types. This will provide valuable information as a starting point for future research efforts as well as the development of guidance and standards for the chemical industry.

Methods

The survey was sent out to a target audience of chemical and process engineers found in specific community groups within the social media platform LinkedIn. This target audience was selected as representing those in industry involved in the design, implementation and optimisation of chemical processes. They would be the "intelligent customer" responsible for the procurement of new technology.

The survey was created and administered using Qualtrics™. This survey platform conforms to GDPR compliance and provides a facility to ensure the anonymity of the data. The survey was also carried out in accordance with The University of York's ethics policy and procedures.

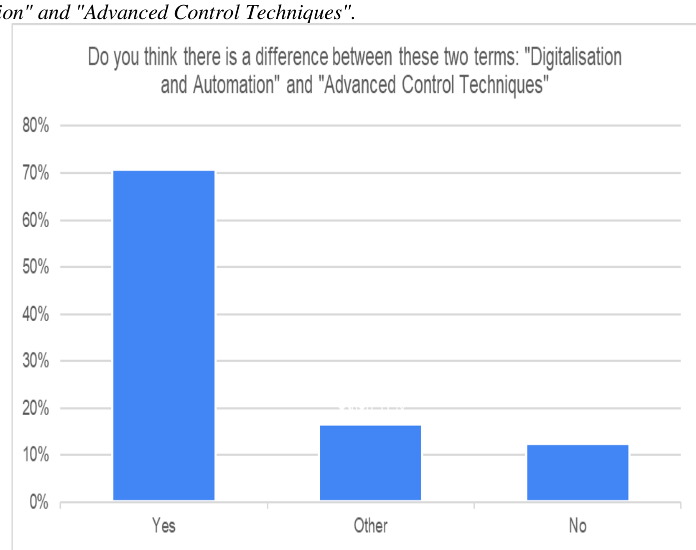
Survey data

The participants were provided with a description of ACS, "The term advanced control refers to a wide range of techniques applied in industrial plants and typically integrating tools from various disciplines – control systems engineering, signal processing, statistics, decision theory, and artificial intelligence."[13] Then they were asked to look at the definition of advanced control and types of technology that fall under the heading of "advanced control" versus "automation and digitalisation".

A total of 54 participants responded to the survey, however only the 24 fully completed survey results were used. If the option of 'all of the above' was selected, then a count for each choice available was added to the data.

Industry experts and practitioners acknowledged a difference between the two terms "Digitalisation and Automation" and "Advanced Control Techniques". As seen in Figure 2 71% answered 'Yes' to the question recognising a difference between the two terms.

Figure 2 presents the percentage split between audience opinions as to whether or not there is a difference between the two terms "Digitalisation and Automation" and "Advanced Control Techniques".



Participants were asked to pick two options from an identical list to describe both terms. Figure 3 shows the two options selected from the list to describe advanced control techniques. Similarly, Figure 4 shows the two options selected from the same list to describe digitalisation and automation. The data shows there is little agreement between participants (see Figures 3 and 4). This shows a lack of clarity amongst industry practitioners which can be exploited by technology sellers in their marketing strategies.

With the option of all of the above added, we can see (in Figure 3) that a narrow majority of industry practitioners think the advanced software listed was ACS. We also noticed that 41% of the participants would describe an ACS as providing increased safety awareness. Whereas only 16% would describe automation and digitalisation as increased safety awareness. This indicates that terminology can guide your perceptions and decisions.

Figure 3 presents the two options chosen from a list to describe advanced control techniques.

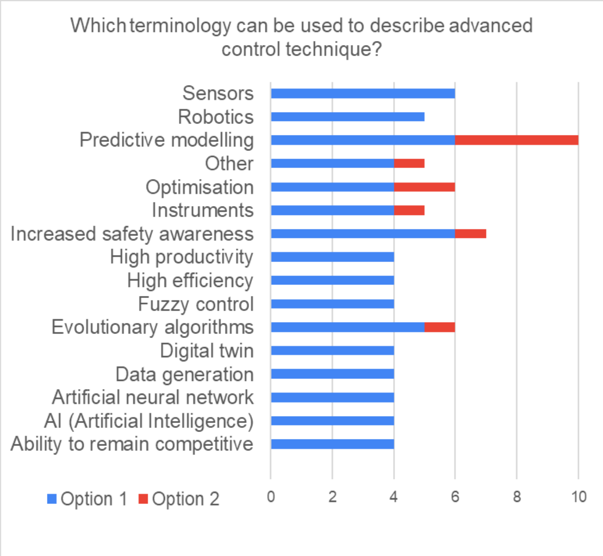
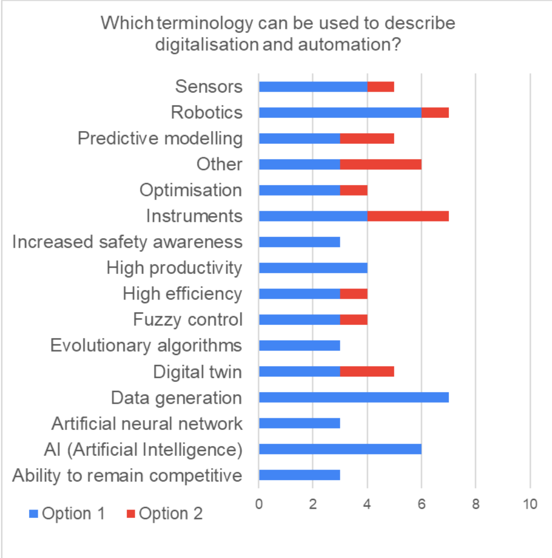


Figure 4 presents the two options chosen from a list to describe digitalisation and automation



Figures 3 and 4 show a lack of consensus this could infer people have too many choices or not enough relevant information. In the next section, we discuss the impact of a lack of clarity in terminology being used in the chemical industry and in particular the impact on the perception of risk

4. Analysis of how the confusion in terminology impacts the perception of risk

Adopting new, not understood, technology on high-hazard chemical sites where all hazards and risks associated have not been fully understood can have serious repercussions. We can ask the question if adopting new technologies to control our processes is adding further complexity to already complex systems. It is especially relevant as there is limited knowledge of the unintended interactions from using advanced control systems.

There is a commencement in literature that shows a gap regarding the lack of understanding and knowledge surrounding the effects of the rapid transformations in technology types and their exponential uptake in industry. Khan et al (2021) state, “As the chemical industry moves to adopt new technologies it will have to deal with the complex issues created by advances in control systems and create a more collaborative intelligent plant” [14].

Plants using new technology to control high hazards need to be safe. The traditional control methods as stated earlier are subject to rigorous standards and guidelines as well as expertise. All the controls in place to ensure traditional control methods are effective with no regular occurrences of explosions on chemical sites in the UK or Europe. It should be noted that improving chemical safety is not the primary goal. Our concern is that it could get worse.

There is a suggestion in literature of a psychological impact of using positive messages associated with new technology. This could impact the user's understanding of the technology and subsequently impact risk perception. Eitzel et al (2017) [15] explore the importance of terminology by describing that terminology is a key factor in humans “constructing mental models of the world around them. They surmise that "terminology matters as what we call things is linked to what we think, language primes us to see certain things and not others". For example, popular console games advertise their product as providing a much-needed break to relax on your own paradise island. There is no small print to inform the consumer of the negative effects of playing the game, such as, prolonged use may cause sleep disruption, affect eye health, lead to joint pain etc. Similarly, the tobacco industry was forced to highlight the negative impacts of smoking.

4.1 Impacts on the perception of risk affecting process safety.

This paper is looking at the current issues related to terminology and their subsequent impacts on safety. Specifically looking at how terminology can affect the perception of risk. Risk is important because it provides awareness of where the potential weak points are in an organisation. This is especially relevant for a chemical company as the repercussion of not knowing where things can go wrong can lead to catastrophic consequences.

A significant portion of the UK chemical industry is subject to the Control of Major Accident Hazard (COMAH) Regulations 2015. The governance by the UK Health Safety Executive (HSE) requires organisations to demonstrate their ability to put in place the necessary precautions to prevent a major accident that could impact people and the environment. This is accomplished by a risk-based process safety (RBPS) management system. All activities are designed to prevent a major accident that could impact people and the environment [16]. If the perception of risk is affected, then it will directly impact all PS activities and in the worst case lead to a major accident.

Earlier we identified two avenues where terminology impacts risk perception. Firstly, the psychological impact and secondly using terms which have different technical meanings. Experience and literature show that these can be split further. The four areas are;

1. Too much information, As new technology is going through a rapid vertical growth rate the information regarding it also has a similar parallel rate of growth. There is a vast amount of information about new technology via many forms of marketing media such as adverts, blogs, social media posts and articles in relevant magazines. All these sources of information use their own terminology to describe new technology. [17]

This is true for the chemical industry due to the global reach of social media platforms. These are not only used to advertise new technology, but they also post people's opinions on the latest technology. This makes it difficult for integrators to know what information to trust. The need for guidance and standards with respect to new technology would help greatly.

There is so much information out there that Hossari et al (2019) have come to a similar conclusion about the number of terms being used for new technology has created a challenge. They suggest a tool which, "automatically detects the existence of new technologies and tools in text with the aim to help the users to build the knowledge about these technologies". However, both researchers and end users need to have clear, concise and relevant knowledge about new technology. Such as how it works, what the comparable safety standards are etc.

2. Misleading terminology, Garcia and Catalone (2001) conducted a literature review of typology surrounding the term "innovation of new technology". With the aim to get industry and researchers to talk in a common language. The literature review found that engineers and technology producers were using widely different descriptive words for the term innovation of new technology. This created a large vocabulary to describe the innovation of new technology and has also resulted in confusing definitions. [18] They give the example of the term "radical innovation of technology" which suggests there has been a revolutionary change in thoughts and ideas. However, in reality, changes are quite often incremental. For example, the technological changes in new mobile phone models are quite often incremental rather than "radical". We could reason that this is mainly due to the consistency of employees such as engineers and technicians within organisations. Terminology can be misleading, for example, the term "radical innovation of technology" also makes you think that innovation is unique rather than improving the original design. There needs to be congruency in language between the producers of the technology, the marketers' and the end users.

The maritime industry is having similar issues with the terminology being used having a negative impact. As with many industry sectors maritime has also started its journey in converting to automation and digitalization. Hult et al (2019) explain the term autonomous ships can lead to potential recruits thinking seamen/women are no longer viable career routes as ships are becoming autonomous. This will eventually lead to a shortfall in proficient skill sets. They conclude a need for aligning technical terms to their true meaning whilst updating terminology at educational institutions and organisations. [19]

Both examples discussed highlight the need for clear transparent language to be used in industry, research activities and educational curriculums.

3. Too many glossaries, The European Food Safety Authority (EFSA) commissioned a review of all terminology linked to risk assessment by a scientific community. The aim, not dissimilar to other sectors in the process industries, is to "improve transparency and reduce ambiguity; this would consequently develop confidence in, and acceptance of, risk assessments that use different approaches" [20]. The working committee found each separate scientific community had their own glossary and agreed that it comprised of legislative definitions combined with corporate definitions. This has ultimately led to specific terminology at organisational levels across the industry. Again, this is not dissimilar to most sectors within the process industries. The conclusions were a need for a clear interpretation of complicated scientific terminology and at the same time keeping an accurate understanding of the terms used. In order to avoid confusion and exploitation by technology developers both transparency and accuracy are needed for the term advanced control systems.

4. **A lack of consensus**, professionals who remove tumours formed a focus group with the intention of generating a glossary of terms which would allow peers to review contrasts in technologies used to remove a tumour, the resultant outcome and any thoughts. The group first classified the different therapies available for removing a tumour, then differentiated between the types of imaging technology and their roles in guiding the professional in removing the tumour and lastly differentiated between pathological and imaging findings. The focus group emphasised the importance of "consensus" in terminology is needed as new technologies emerge [21]. We have a comparable concern with the term ACS. Due to the term ACS having a wide range of control technologies associated with it, it seems necessary to classify the technologies available as part of future works. However, without consensus between technology developers, industry and researchers, confusion in terminology will remain at large and impact the perception of risk.

In conclusion, the discussions on terminology and their subsequent impacts on safety have shown that the above areas have a negative impact on the perception of risk. Firstly, the psychological impact of using terminology versus clear and transparent wording to describe technological function is amplified by the volume of misleading information in the public arena. Secondly, using terms with different technical meanings to more common terminology is augmented with numerous glossaries and a lack of consensus.

Ambiguous terminology can lead to the perception of risk being affected, directly impacting on all process safety activities and in the worst case leading to a major accident. The extent of the misconceptions creating safety implications is difficult to quantify. This paper provides awareness of the issue and can act as a starting point for future works to create an initial taxonomy for advanced control.

5 Defining the term ACS

Providing a definition for ACS in today's market is important to address the potential safety risks posed by advanced control systems which are not always apparent from the way they are described by proponents and vendors. The analysis from reviewing literature and surveying experts for their understanding of the terminology being used led to determining that terminology impacts the perception of risk. This directly impacts process safety, especially activities that allow us to identify hazards and risks. Therefore, our argument stands that there is an effect on the perception of risk of the new advanced control systems. To progress the definition further we look at the parameters to define an ACS.

5.1 Parameters to Define an ACS

The first consideration was the building of a good catalogue of terms which will provide clarity to see and understand the types of technologies included in an ACS. This transparency will enable both industry practitioners and researchers to decipher the benefits and limitations of the ACS. However, Eitzel et al found it difficult to associate a singular term for all groups of people. This has also been noted by Garcia et al (2003) [18]. The next steps are deciphering what characteristics should be included in the definition [22], [23].

Therefore, at this early stage in researching such matters, we are not going to distract our focus from specifying a set of technologies to the definition of ACS. We recognise there is value, instead, we start with assigning ACS's key properties such as functionality and capability.

Focusing on key properties that matter will provide insights into the ACS which will help us determine how to use it safely and appropriately. Which will aid in understanding the hazards and risks associated with the ACS. If the aim of an ACS is to mimic a human, then we can compare the current expectation of a human to determine what we should expect from an automated system. We attempt this as it aids us in the development of the definition of an ACS.

We compare a scenario of driving a car which experiences a fault with the braking system. The analogy used here is to consider how a human would react to a simple situation of reacting to a fault in the vehicle. From this, we extrapolate to aid in determining what we expect from the ACS in the same situation. For example, a human driving a car hears a noise and starts to anticipate that there might be a situation occurring. Next, they start to explore different options and feel that the brake pads are sticking, at this point, the driver understands what is happening and knows the situation. The driver takes action and comes to a controlled stop. If we apply the same scenario to an automated driverless car, the sensors will hear and feel/recognise a change in the brake pads, the ACS should predict what's happening and take the appropriate corrective actions without anyone coming to harm.
Next, we developed the relationship between the key properties of an ACS and how we expect the ACS to behave. This collective thought process led to summarising the key properties and their expected behaviours into three stages 1. Complexity, 2. Predictability and 3. Actionability. This is seen in Table 3.

Table 3 shows the key properties of an ACS that will provide insights into the ACS

The key properties of the ACS	What behaviours are expected from the ACS property in terms of function and capability
Complexity	The ACS's ability to anticipate situations and understand what is happening. In the real world, a seasoned chemical engineer would be able to do both based on experience and knowledge accumulated.
Predictability	The ACS's ability to predict excursions beyond a safe operating envelope and predict any emergent issues. Practically we need to know if the ACS can control the process or provide information to the current people with the right skills to take appropriate action.
Actionability	The ACS's ability to know how to adjust the process and manage emergent issues. If it cannot then be able to stop the process or get a human to stop or adjust the process.

Diagram 2 depicts the expectations of an ACS. The key explains that the hexagonal shape shows the property of the ACS whereas the text in the rectangle shape is the expected behaviour. We note that the properties, although always present, are more significant at different times as depicted by the dotted line in Diagram 2.

The breakdown of the properties and expectations of an ACS will aid future works to develop a taxonomy. The development of a definition for ACS will enable the production of a taxonomy that will aim to clearly define the technology, its functions and the expertise level required to handle it safely.

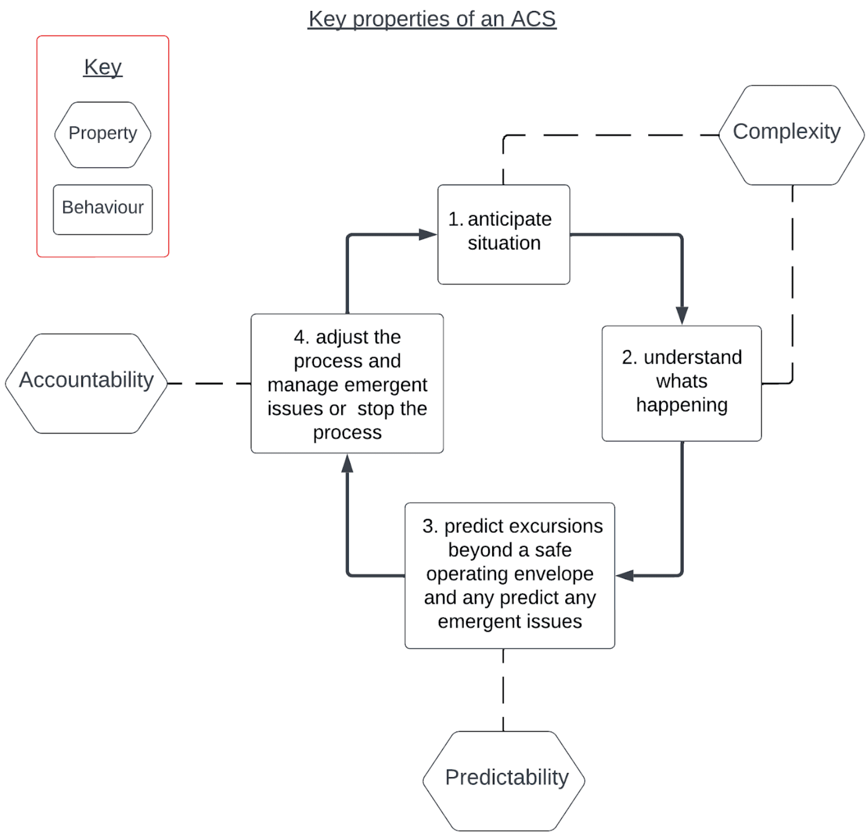


Diagram 2 explains the relationship between the key properties of an ACS and what is expected of the ACS. The key explains that the hexagonal shape shows the property of the ACS whereas the text in the rectangle shape is the expected behaviour.

5.2 The proposed definition of ACS

Phrases such as ACS and Automation and Digitalisation are widely used and do not provide clear information regarding the type of technology being referred to. This causes confusion as technology has developed over the decades. Given that we also realise that confusion in terminology can impact the perception of risk which directly impacts process safety. Especially activities which allow us to identify hazards and risks. Therefore, an interim solution is offered with the following definition of the term "advanced control system":

The term "advanced control system" is defined as a process design which is automated to a point where a human does not have the final say and cannot see the decisions being made.

This definition of ACS is a true indication of new technology which is difficult to predict and understand such as an ACS which is used to control high-hazard chemical processes and requires better understanding and clarification of the complexities associated with it.

6. Conclusion

The terminology used to describe new technology is vague and often leans to the positive which, as described, can lead to misconceptions. The extent of the misconceptions pertaining to process safety activities is difficult to quantify. However, this paper provides awareness of the issue.

In addition, we recommend some future works. The gap in knowledge should be addressed with further research in identifying the training and development needs to ensure we have the correct skill sets to deal with ACS. Next progress to a gap analysis of the training needs and the best methods to deliver this training to current industry practitioners and the next generation of chemical engineers at university. Lastly, future research activities should also look into how we evaluate the success of the training and what are the criteria to assess against.

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