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STAYING IN NESTED LOOPS
A SYSTEMIC VIEW

'Staying in the loop' relies on continuous feedback within and between organisations to allow individuals, groups, and organisations to make informed decisions. In this article, Erik Hollnagel explores these 'nested loops', along with the gaps between imagination and reality, with implications for learning, design, training and management.

KEY POINTS

- **The 'law of requisite variety':** Effective regulation depends on the regulator's ability to match the complexity of the system it controls. The 'law of requisite variety' states that the regulator must have sufficient variety to handle all possible states of the system, as this is essential for maintaining control.
- **Bridging work-as-imagined and work-as-done:** There is often a significant difference between how work is envisioned by designers, trainers, managers (work-as-imagined) and how it is (work-as-done). Bridging this gap requires the ability to foresee potential future conditions and discrepancies – 'requisite imagination'.
- **Learning from experience:** Effective control relies on feedback and learning from experience. While individuals tend to adapt and learn dynamically, collective (organisational) learning is slower and more limited. Delays and distortions in feedback can impede effective control, making timely and accurate feedback crucial for decision-making at all levels.
- **Continuous feedback:** Staying in the loop depends on continuous feedback inside and between organisations, which enables individuals or organisations to make informed decisions to increase requisite imagination, and reduce as far as possible the gaps between work-as-imagined and work-as-done.

THE SHARP END (OPERATOR) LOOP

To stay in the loop means continuously to receive feedback about how something develops, such as flying an aircraft through a sector or walking through an unfamiliar metropol to find your hotel. Staying in the loop is but also (and more importantly) to be able to use the feedback to choose the appropriate response or intervention, in order to stay on course and remain in control.

Whoever or whatever maintains control is usually called a 'regulator'. A regulator can be an organisation. This is probably how most people interpret the word. Examples of organisations are the Federal Aviation Administration (FAA) in the US and the European Aviation Safety Agency (EASA) in Europe, plus the countless regulatory bodies that permeate modern societies. A 'regulator' can also be a person more generally, such as a pilot in a flight deck or a

controller at a working position. At the simplest level, a 'regulator' can be a simple analogue mechanism. A good illustration of that is the purely mechanical centrifugal 'governor' that James Watt introduced in 1788 to regulate the flow of steam into his steam engines. Prior to that, it had been done manually by an operator (hardly an exciting job). The term governor points to the roots of cybernetics, "*the science of control and communication in the animal and in the machine*" (Wiener, 1948). Cybernetics also formulated a basic principle of control known as the law of requisite variety (Ashby, 1956). This is particularly relevant to this issue of *HindSight* on people in control.

REQUISITE VARIETY

The law of requisite variety (LoRV) simply states that the variety of the outcomes (of a system or a process) only can be decreased by increasing the variety in the regulator of that system. Another way of expressing that is the so-called good regulator theorem (Conant & Ashby, 1970), which states that "*every good regulator of a system must be a model of that system*". We usually refer to our understanding of the target system as a model of that system, although it is rarely a model in the formal sense.

In everyday language, the LoRV simply states that if something happens that the regulator either cannot recognise or cannot respond to, then control will be lost. This is a condition that we all experience from time to time at work and at home, but hopefully not too often. The feedback provides the information that allows us to determine whether the actual state or position corresponds to the intended state or position. We can then use any noted difference to predict the outcome of possible action alternatives and choose an appropriate corrective intervention.

REQUISITE IMAGINATION

The purpose of the 'regulator' is to respond in a way that ensures that the developments being controlled stay on course. When we build a regulator, either a piece of technology or a human ('built' via training), the critical issue is how to ensure the requisite variety. A major problem here is the difference between work-as-imagined (WAI) (what the designers think can happen; see Shorrock, 2020) and work-as-done (WAD) (what actually happens). To do so successfully requires so-called requisite imagination (Adamski & Westrum, 2003). This was proposed as an analogy to requisite variety. Requisite imagination is the ability to imagine key aspects of the future one is planning or designing.

The difference between work-as-imagined and work-as-done was not a problem for the centrifugal governor mentioned earlier. Here, the requisite variety was limited because the steam engine was a strictly deterministic system. But this difference is a problem for the complex socio-technical systems of today, where the requisite variety is huge, along with the number of things that can possibly go wrong.

> "The difference between work-as-imagined and work-as-done is a problem for the complex socio-technical systems of today."

LEARNING AND THE LIMITATIONS OF EXPERIENCE

Requisite variety and requisite imagination are especially problematic for those preparing the training needed to gain the competence required for a specific job, such as a pilot or controller. These requisites are also a problem for writing the procedures that people can refer to and rely on in critical situations. A problem in developing guidelines and procedures is that this is based on the experience from the limited set of events that have happened plus whatever people, procedure writers, designers, and law makers can imagine beyond that. But experience and imagination pales against the potentially unlimited set of events that may happen throughout the system's remaining lifetime, as countless experiences show. This gap between imagination and reality occurs particularly because thinking in terms of single components and failures is insufficient for a world where combinations of conditions and actions are known to play a significant role. (This is why a constitution is never sufficient in itself, but has to be supplemented with multiple amendments.)

In light of these gaps, the solution for people at work is often to depend on their natural ability to learn from experience, in the hope they can recall it when the need arises. This means that the potential to learn is essential for effective control and for staying in the loop.

Being in control can more formally be said to require the four systemic potentials developed by Resilience Engineering (e.g., see Hollnagel, 2009; Hollnagel, Licu & Leonhardt, 2021; Hollnagel, 2025): 1) the potential to respond, 2) the potential to monitor, 3) the potential to learn, and 4) the potential to anticipate).

In practice, people will learn by themselves, and from others, and hence cumulatively improve their requisite variety. But often the control is by an organisation. Organisations can, of course learn (or rather the people in an organisation can learn), but organisational learning is often limited to avoidance learning of what not to do and what to mitigate, defend against, constrain or eliminate. Such learning is furthermore slow and may not be very reliable. While we train people individually and sometimes in teams, we do not yet train organisations, except via the introduction of rules and standards. Instead, we train their leaders in the naively optimistic hope that this somehow will rub off on the organisation.

THE SHARP END AND THE BLUNT END

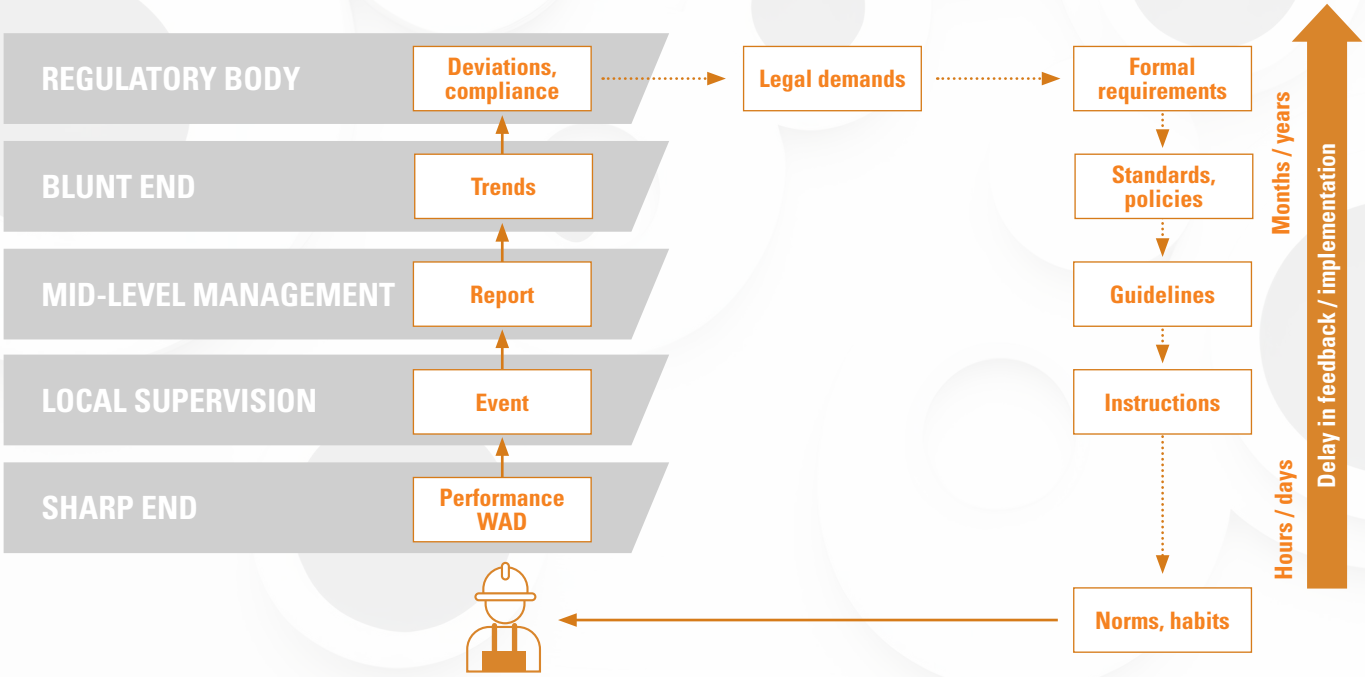
The expression 'to stay in the loop' is usually reserved for people who work at the 'sharp end'. That term was introduced by Reason (1990), although he called it "the front end". The sharp end refers to the people who "*actually interact with the hazardous process in their roles as pilots, physicians, space controllers, or power plant operators*" (Woods et al., 1994, p. 20). In former times they were also referred to as workers at the coalface, and in the context of *HindSight*, they include the pilots in the cockpit.

The work of people at the sharp end must meet criteria and take place in conditions that have been defined by others, who are usually not doing the work themselves (and therefore not directly exposed to any harmful consequences, and who may not even be able to do the work – even if they once did). These people work at the 'blunt end', but as Professor Karlene Roberts cleverly observed, "*everybody's blunt end is someone else's sharp end.*" And just as people at the sharp end must be in the loop to do their work, so must people at the blunt end.

Any complex system, such as air transportation, therefore comprises multiple feedback loops nested within each other (Figure 1). We know from many psychological studies that human performance deteriorates if feedback is delayed. And in this respect, people at the blunt end are clearly at a disadvantage, as described by Figure 1. The information they get about what actually happens (work-as-done) has been filtered and interpreted multiple times in ways that are mostly unknown.

This is why high-level recommendations of a very general nature are often of limited practical value. Add to that a significant delay of months and potentially years to find out whether the recommendations had the intended effect, and it is clear that the managers at the blunt end are not, and cannot be, 'in the loop' as much as they might hope. And the conditions are even worse for a goverment regulator, who faces a nearly impossible challenge.

Figure 1: Multiple nested feedback loops in a complex socio-technical system



CONCLUSION

In conclusion, staying in the loop depends on continuous feedback inside and between organisations, which enables individuals or organisations to make informed decisions. This is made difficult by the delays and distortions that can occur as information moves up the hierarchy and the inevitable gaps between work-as-imagined and work-as-done. Poor feedback forms a challenge to learning, designing and managing, as revealed in the sometimes stark differences between designed procedures (and training) and actual operations.

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The only way forward is to reduce, as far as practicable, the gaps between work-as-imagined and work-as-done, via more collaboration between the so-called sharp and blunt ends, to understand how work is actually done and decide on how it might best be done (to keep the variability of work-as-done within acceptable limits), knowing that this may never correspond to our imagination.

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