Reducing the gap between designers and users, Why are aviation practitioners here again?

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INTRODUCTION

Our approach to designs for human-system integration resulted in designs with reduced margins to manage and work with uncertainty and surprise within the work systems. This paper argues that technological designs often underperform compared to the promised benefits delivered. The reason for this is principally because designs have been based on a strategy where practitioners e.g., ATCOs, pilots etc, are expected to take over in abnormal conditions - the so called 'left-over' design strategy' or the (Inagaki, T, 2014, p235)). Inagaki also argues, citing Rasmussen & Goodstein, that there is a need to retain the human in the system to 'complete the design, so as to adapt to the situations that designers never anticipated' (Inagaki, 2014, p235) We argue that the need to change this philosophy of design is necessary, as Boy argues: "We cannot think of engineering a design without considering the people and the organisations that go with it" Boy argues (Boy, 2020). The operating environments of interest here, complex macro-cognitive work designs, are what Boy refers to as socio-cognitive systems (Boy, 2020) and are confronted with the challenge of digitisation and integration of artificial intelligence.

Uncertainty and surprises will always be an element of complex systems,

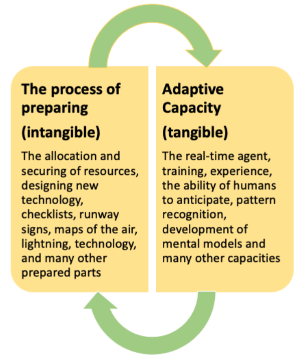
Complexity research (Flach, 2014; Heylighen, Cilliers & Gershenson 2007, Cilliers, 2000) and the study of chaotic dynamics have demonstrated that uncertainty and surprise are fundamental aspects of the world around us (Eisenberg, Seager, Alderson, 2019; Lanir, 1983). Instead of an ordered system, such as machines, the aviation system is a complex system whose properties emerge from nonlinear interactions of numerous different agents. These interactions, and the interplay between them, create uncertainty and fundamental surprises (Eisenberg, Seager, Alderson, 2019. Woods et al, 2010, Lanir, 1983) which need to be managed in ways where as far as possible lead to being able to stay in control (McDaniel, Jr., Driebe, 2006).

The human or the machine?

Today's aviation system consists of many different actors and agents that affect the ability to respond to uncertainty and surprises. There is a political level, an organisational level, a social dimension, training of practitioners, and numerous others. Knowing this, the only model of a human system is the system itself. We assume that there is a basic shared model of operation such as common ground in joint activity (Klein et al, 2005) between different actors. The basic model of operation consists of two interdependent processes. One is the process of preparing the other is the constant real-time adaptive capacity - that is the capacity to adapt to situational

and fundamental surprises (Eisenberg et al 2019) and performance variability whilst sustaining production and system goals, which practitioners deliver principally.
The process of preparing entails procedures, checklists, runway signs, maps of the air, lightning, technology, the allocation and securing of resources, designing new technology and many other activities. Organisational adaptive capacity is developed through training, experience, the ability of humans to anticipate, pattern recognition, mental models, the ability to respond in real-time and many more skills needed to respond to changes, uncertainty and surprises that we know will occur.

Fig 1. The basic model of operation



Designing technology to handle uncertainty and surprises requires that the designers of technology do so with this characteristic of 'work' in mind. In order to do this designers, need a complete understanding of the uncertainty and surprises that will emerge within the aviation system. However, this requires perfect knowledge. As we all know, perfect knowledge is never available e.g., Air traffic controllers (ATCOs) quite often improvise in situ to meet the challenges of traffic imposed by novel events, unfortunate actions and shortcomings of the work system. In the ATM system balancing efficiency and thoroughness, involves making improvisations and departing from existing procedures under conditions of time pressure, uncertainty, and high workload. The rapid expansion of information technology has increased the amount of information presented to ATCOs without any assistance in how to make sense or to anticipate the current situation or future trends. Quite frequently ATCOs are dealing with a complex and dynamic environment that requires them to attend to multiple events, anticipate aircraft conflicts and comprehend or make sense of evolving scenarios.

Experience has shown that staying in control when exposed to surprises is the main challenge in today's very safe aviation system. If you can eliminate uncertainty and surprises, you can remove real-time control of the system by the human. Todays' rare accidents are characterised by complexity and surprise rather than by broken parts or components. The latest prominent example is the 737 max accidents (Nicas et al, 2019). Boeing management decided that the designers of the technology could foresee all possible uncertainty and decided to keep the human practitioners out of the loop. It is unrealistic, to assume that uncertainty and surprise can be eliminated. This leads to a system requirement for designs to have the human actively involved in the control functions of the system.

Two different mental models

Historically, the aim for designing complex technical systems has been to replace or limit the authority to act of the human practitioner in real time operational control and management of the systems activities. Another design approach has been to partially remove the human practitioner and create a strict task-sharing environment in which automation deals with routine tasks and events, while the human is exclusively responsible for rare high complexity situations.

In essence, these system activities at the micro level are the work i.e., the purposeful activity of the real-time system. Thus, this perspective of work reduces the purposeful activity as it reduces the involvement of the human practitioner. In particular it reduces the ability to respond to uncertainty and surprise.

This approach is driven by the idea that it is possible to substitute the human practitioner with technology that includes prepared responses to uncertainty and surprises. Lisanne Bainbridge describes this approach, in her 1988 paper (Bainbridge, 1988): *The designer's view of the human practitioner may be that the practitioner is unreliable and inefficient. so should be eliminated from the system.*

An alternative approach, is where systems are designed to be able to support management and adaptation of uncertainty and surprises by collaboration and co-allocation between technology and the human practitioner (Bradshaw, 2011). This approach has been called the joint cognitive approach (JCA) (Hollnagel and Woods, 2005) and is based on the notion that the human practitioner stays in control and that we design for the human practitioner to know what the technology is doing, a design that emphasises common ground.

Klein extends and amplifies this perspective further in the two views in the table below (Klein 2022) that represent designers and end users' perspectives:

	Capabilities	Limitations
The designers view	How the system works: by its parts, connections, causal relationships, process and control logic.	How the system fails: Common breakdowns and limitations (e.g., the limitations of the human)
The users view/JCA	How to make the system work: Detecting anomalies, performing workaround and adaptations.	How the users get confused: Complexity and false interpretations.

Table 1: Differing design requirements of system designers and system end users (Klein, 2022)

Taking the designer's view there are some caveats that we have to be aware of. Again, Bainbridge describes it in this way: One,

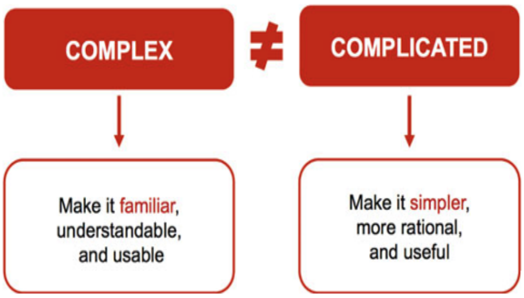
- that designer assumptions can be a major source of operating problems and,
- the second problem is that the designer who tries to eliminate the practitioner, the left-over functions, still leaves the practitioner to do the tasks which the designer cannot think how to automate.

- An additional problem is that the most successful automated systems, with rare need for manual intervention, may need the greatest investment in human practitioner training.

Taking the joint cognitive and the human system integration approaches (Hollnagel, Woods, 2005; Boy, 2020) are extant philosophies for collaboration between technology and the human which retain control in real-time operation.

Design for collaboration between technology and humans – design a social cognitive system

How do we meaningfully bring technology and social actors – the designer and the user - together to match a complex world with its inherent complex adaptive solutions that are playing out in real–time?



The challenge becomes, in a complex world compared to a complicated word, , how do we reconcile the different mental models of the different actors to create designs that enhance adaptive capacity? Figure 2

The dualism of the two different mental models becomes more complicated when considering design and the engineering of the design, for complex socio-technical systems.

Design for complex socio-technical systems, can be seen as an exercise in conflicting value systems (Baxter & Somerville, 2011, citing Land 2009). For example:

- *Design values with a fundamental commitment to humanistic principles*: the designer aiming to improve the quality of working life and job satisfaction of those operating in and with the system.
- *Managerial values*: the principles of socio-technical design are focused on achieving the company or organisational objectives especially economic ones

These two sets of values conflict. And we argue that this tension can contribute to a decrement in system adaptive capacity as well as adding costs to the system's effectiveness and its ability to achieve system production, goals and objectives.

One of the driving arguments for automation is that costs of production are reduced because there are fewer human costs - be it training, the reliability of the practitioner, the inefficiency of the practitioner. Designs that seek to optimise managerial values can have the effect - intentional or otherwise -to privilege the managerial objectives and in doing so constrain the humanistic design. The consequences of this are that the practitioners' degrees of freedom are reduced; buffers and margins are impacted in ways that limit the ability of the system to maintain and sustain adaptability when confronted with uncertainty and surprise events and thereby making the system less effective. Additionally, increasing the distance between the practitioner, and the system reduces the practitioner's ability to intervene in case of unexpected events:

Work changes. When work changes there are consequences on the practitioner's ability to create strategies that can exploit system characteristics of agility and flexibility, in other words adaptive capacity. Boy (Boy, 2020) refers to this as a form of smart integration: designing for innovative complex systems - that exploit the ability to understand increasing complexity. This means embracing complexity. What are we designing for?

A design that embraces complexity will adopt the opposite of the reductionist view – which means reducing or eliminating the effects of complexity, by eliminating or reducing the role of the human. As opposed to designs that embrace and design for complexity by matching emerging system behaviours with creative emergent human real time responses.

Conclusion

In this paper we argue that we need to move towards designing a socio-cognitive system. This is proposed as a way forward to reduce the distance between practitioners and designers so that designs incorporate joint activity that supports common ground.

To make that possible, we must embrace complexity, uncertainty and surprises rather than trying to eliminate it. In doing so the role of the human practitioner is recognised and sustained, which permits more efficient and effective operation in real-time. Furthermore, such an approach can lead to maintaining job satisfaction, practitioner involvement and the real-time learning and adjustments of patterns of activity associated with complexity, uncertainty and surprises.

One of the means to achieve a constructive approach to the design of effective and meaningful human-system integration is through new ways of working together. These need to be institutionalised and embedded by the Regulator. In the recent Boeing episode, the manufacturer was doing the regulators job (Nicas, J. *et al*, 2019).

Further areas for consideration are a coherent transition plan should be derived to identify the needs of management and the human practitioner in complex socio-cognitive systems. Another question is whether we are deceived by the optimistic predictions of costs saved by tools and method of operations without the human practitioner.

References

Bainbridge L (1983): Ironies of automation. *Automatica* 19:775–779.

Baxter, G., & Somerville, I. (2011). Socio-technical systems: from design methods to systems engineering. *Interacting with computers* Vol.23: 4-17

Boy G, (2020). *Human-systems integration*. CRC Press

Bradshaw, J., Feltovich, P., & Johnson. (2011) . Human-agent interaction. In G. Boy (Ed), *The handbook of human-machine interaction* p. 283-303 Ashgate

Cilliers, P. (2000), *Complexity and postmodernism: understanding complex systems*. Routledge

Eisenberg, D., Seager, T., Alderson, D.L. (2019). Rethinking resilience analytics. *Risk Analysis* DOI: 10.1111/risa.13328

Flach, J. (2012), Complexity: learning to muddle through. *Cogn Tech Work* (2012) 14:187–197
DOI 10.1007/s10111-011-0201-8

Heylighen, F., Cilliers, P., Gershenson, (2007). Complexity and Philosophy. In Ed. J. Bogg, R. Geyer. *Complexity, Science and Society* (1ST Edition). CRC Press.

Hollnagel E, Woods D (2005): *Joint Cognitive Systems: Foundations of Cognitive Systems Engineering*. CRC Press, Taylor and Francis.

Inagaki, T. (2014). Human-machine co-agency for collaborative control. In Eds, Yoshiyuki, Sankai; Kenji Suzuki, Yasuhisa Hasegawa: Cybernics: fusion of human, machine an information systems. Springer

Klein, G. (2022). *The war on expertise*. Novellus. https://novellus.solutions/insights/podcast/war-on-expertise-how-to-prepare-and-how-to-win/.

Klein, G., Feltovich, P.J., Bradshaw, J.M., Woods, D.D. (2005). Common ground and coordination inf joint activity. In Eds W. B. Rouse & K.R. Boff, Organisational Simulation: Wiley

Lanir, S. (1983). *Fundamental surprises*. Tel Aviv: Centre for strategic studies

McDaniel P.R Jr., & Driebe D.J. (2006): *Uncertainty and Surprise in Complex Systems: Questions on Working with the Unexpected*. Springer Publishing.

Nicas J, Kitroeff N, Gelles, D, Glanz J. (2019). Boeing built deadly assumptions into 737 Max, blind to a late design change [Internet]. New York: The New York Times; 2019 Jun 1 [cited 2019 Oct 17]. Available from https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html

Woods, D.D. (2010) Fundamental surprise. In Ed.D.D. Woods, S.W.A Dekker, R. Cook, L, Johannesen, N. Sarter. *Behind human error* (2nd Edition). CRC Press