

# Beyond SHELL: Integrating Self-Consciousness into Human Factors Systems (The SSHELL Framework)

Astha Gill

ISE, India

---

## SUMMARY

The classical SHELL model has served as a foundational tool in Human Factors analysis, structuring the interactions among software, hardware, environment, and liveware. However, in modern high-stake systems, many performance variations arise from intrapersonal dynamics that the traditional model does not capture. This paper introduces The SSHELL Framework, a theoretical evolution that embeds Self-consciousness (S) as a core regulatory dimension within Human Factors systems. By addressing the role of internal self-regulation- awareness, emotional control, and reflective judgement- SSHELL redefines how human reliability and safety are understood. The framework bridges cognitive psychology, neuroscience, and ergonomics to propose a more conscious systems approach. Its relevance spans Aviation, Healthcare, and Defence, and points to future adaptability in Education as Human Factors principles extend into emerging domains. SSHELL thereby offers a conceptual bridge between human awareness and system resilience.

## KEYWORDS

SSHELL Framework, Human Factors Evolution, Self-Consciousness Integration, SHELL Model

---

## Introduction

Human Factors (HF) has long recognised that system performance and safety are shaped by the interaction between humans and the systems within which they operate. Originating in safety-critical domains such as aviation, HF has progressively evolved to address not only physical ergonomics but also cognitive, organisational, and socio-technical dimensions of work.

The SHELL model has played a central role in this evolution. By structuring interactions among Software, Hardware, Environment, and Liveware, it provides a practical framework for identifying mismatches that may degrade performance or compromise safety. Its enduring value lies in its simplicity, adaptability, and emphasis on the human as the focal point of system interaction.

However, as operational environments become increasingly complex, cognitively demanding, and socially embedded, certain forms of performance variation are not fully explained by external interfaces alone. In many contemporary systems, deviations arise from intrapersonal processes such as internal judgement, emotional regulation, self-monitoring, and reflective control. These processes influence how individuals engage with system elements, particularly under conditions of uncertainty, stress, or high cognitive load.

This paper introduces the SSHELL framework, a conceptual extension of the SHELL model that explicitly integrates Self-consciousness (S) as a core regulatory dimension. Within this framework,

self-consciousness refers to the individual's capacity for internal self-regulation, encompassing awareness of cognitive and emotional states, regulation of responses under pressure, and reflective judgement during action.

By distinguishing between observable behaviour and intrapersonal regulation, SSHELL enhances the explanatory and diagnostic capability of the SHELL model. The framework is applicable across established safety-critical domains such as aviation and extends meaningfully into emerging contexts such as education, where internal regulation plays a foundational role in performance. In doing so, SSHELL aligns with the EHF 2026 theme of *Adapting to the Future* by addressing evolving demands on human performance in complex systems.

### **The Classical SHELL Model: Strengths and Emerging Gaps (EHF-Aligned)**

The SHELL model has been widely adopted within Human Factors due to its clarity and operational utility. By structuring interactions between Software, Hardware, Environment, and Liveware, the model provides a systematic means of identifying mismatches that may affect performance and safety. The positioning of Liveware at the centre reinforces the principle that humans are integral to system functioning rather than peripheral components.

Within aviation, the SHELL model has proven effective in analysing issues related to interface design, procedural usability, environmental stressors, and communication within teams. Its flexibility has supported application across a range of operational contexts, contributing to its longevity within Human Factors practice.

Despite these strengths, the Liveware component remains necessarily broad. While it captures the human as a system actor, it does not differentiate between *observable behaviour* and the *internal regulatory processes* that shape that behaviour. As a result, when performance variation arises primarily from intrapersonal factors rather than external mismatches, the explanatory resolution of the model is limited.

As Human Factors increasingly addresses complex, adaptive, and socially embedded systems, this limitation becomes more evident. In emerging domains such as education, performance is shaped not only by instructional design or environment, but by learners' and educators' capacity for internal regulation, reflection, and agency. These influences are system-relevant, yet remain weakly represented within conventional HF models.

The SSHELL framework is proposed in response to this gap, extending the explanatory scope of SHELL while preserving its foundational structure.

### **Defining Self-Consciousness within Human Factors (EHF-Aligned)**

The integration of Self-consciousness into a Human Factors framework requires a definition that is both theoretically grounded and operationally relevant. Within the SSHELL framework, self-consciousness is not conceptualised in a philosophical or personality-based sense, nor is it equated with self-esteem or introspection. Instead, it is defined functionally, in relation to performance and system interaction.

Self-consciousness, within SSHELL, refers to the individual's capacity for internal self-regulation, including awareness of cognitive and emotional states, modulation of responses under pressure, and application of reflective judgement during action.

It is important to distinguish self-consciousness from related concepts. Situational awareness concerns perception and understanding of external elements in the environment, whereas self-consciousness concerns awareness and regulation of internal states. Personality and attitude reflect

relatively stable individual characteristics, while competence reflects learned capability. Self-consciousness governs how competence and awareness are applied under varying conditions.

In aviation, elements of self-conscious regulation are already addressed implicitly through training practices such as Crew Resource Management and decision-making under stress. However, these elements are often distributed across training constructs without a unifying conceptual anchor. SSHELL provides that anchor by making intrapersonal regulation explicit within the system model.

In education, where Human Factors applications are still developing, self-consciousness plays a foundational role in learning, participation, and resilience. By recognising self-conscious regulation as system-relevant, SSHELL enables Human Factors principles to be applied meaningfully to educational environments, where internal states materially influence performance outcomes.

By formally distinguishing self-consciousness from observable behaviour, SSHELL reframes Liveware as not only an interacting agent, but as a self-regulating entity within the system.

### The SSHELL Framework: Conceptual Structure and Intent (EHF-Aligned)

The SSHELL framework extends the classical SHELL model by explicitly integrating Self-consciousness (S) as a distinct regulatory dimension within the human element of the system. The intent is not to add complexity, but to improve conceptual resolution by making intrapersonal regulation visible within Human Factors analysis.

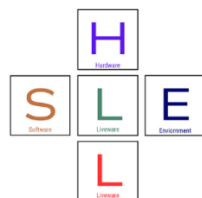
#### Positioning of Self-Consciousness within the System

In the SHELL model, Liveware occupies the central position, representing the human as the primary interacting agent within the system. SSHELL retains this structure while recognising that outward interaction is governed by internal regulatory processes.

Within SSHELL:

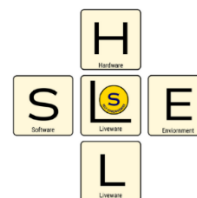
- Liveware represents observable behaviour, skills, communication, and task execution.
- Self-consciousness (S) represents the internal regulatory processes that shape how behaviour is initiated, moderated, and adapted.
- Conceptually, self-consciousness operates prior to and during interaction with system elements. It influences perception, judgement, emotional response, and decision execution before these manifest as observable actions. By modelling this explicitly, SSHELL distinguishes between what the human does and how the human governs what they do.

#### The SHELL Model



SHELL Model
Liveware (Human operator) at centre
Focus on external interfaces (S-H-E-L)
Explains mismatch-induced error
Aviation-specific
Reactive model

#### The SSHELL Model



SSHELL Model
Self-consciousness (S) at centre
Focus on both internal (S) and external (S-H-E-L) interfaces
Explains mismatch + self-regulation failure
Cross-domain universal
Reflective, preventive model

Figure 1. Conceptual representation of the SSHELL framework. Self-consciousness functions as an intrapersonal regulatory layer influencing Liveware interactions.

### ***Distinction between Self-Consciousness and Liveware***

A key consideration in extending the SHELL model is whether self-consciousness is already encompassed within Liveware. SSHELL proposes that while Liveware includes the human as a system actor, it does not adequately differentiate between behavioural execution and intrapersonal regulation.

This distinction becomes operationally relevant when analysing performance variation. Performance breakdowns are frequently attributed to human error without a structured means of examining internal precursors such as degraded judgement, emotional escalation, or reduced self-monitoring. SSHELL provides a framework for examining these precursors systematically.

By separating internal regulation from observable behaviour, SSHELL refines the Liveware construct rather than replacing it. This refinement enables more precise analysis of performance, particularly in contexts where external system conditions remain stable but outcomes vary.

### ***Purpose and Scope of the Framework***

The purpose of SSHELL is to enhance the explanatory and diagnostic capability of the SHELL model in contemporary operational environments. As systems become more cognitively demanding and socially complex, understanding how individuals regulate themselves becomes increasingly important for system safety, reliability, and resilience.

SSHELL is intended to:

- Improve diagnostic clarity in Human Factors analysis.
- Support training and system design that account for intrapersonal regulation.
- Enable extension of Human Factors principles into emerging domains.

In doing so, SSHELL preserves the strengths of the SHELL model while addressing its conceptual limitations.

### ***Diagnostic and Operational Value of SSHELL (EHF-Aligned)***

The primary contribution of the SSHELL framework lies in its ability to enhance diagnostic precision when analysing human performance within systems. While the SHELL model effectively identifies mismatches at human–system interfaces, SSHELL enables analysis of why similar interfaces may lead to different outcomes.

### ***Enhanced Diagnostic Resolution***

Within SHELL-based analysis, performance degradation is commonly attributed to interface limitations, procedural complexity, environmental stressors, or communication failures. SSHELL introduces an additional analytical layer by examining how individuals internally process and regulate these conditions.

By distinguishing external constraints from internal regulation, SSHELL supports more accurate identification of contributory factors, particularly in post-event analysis and training evaluation.

### ***Aviation Domain: Explicitly Naming an Implicit Dimension***

In aviation, self-conscious regulation has long been embedded within operational practice, though not explicitly represented within system models. Training approaches such as Crew Resource

Management and Threat and Error Management emphasise self-monitoring, emotional control, and reflective decision-making under stress.

SSHELL provides a conceptual structure that explains these practices as expressions of intrapersonal regulation. For example, a pilot's recognition of rising stress and deliberate modulation of decision-making pace reflects effective self-conscious governance of performance. While SHELL can identify contributing stressors, SSHELL enables analysis of how those stressors were internally managed.

### ***Education as an Emerging Human Factors Domain***

Education represents a domain in which performance outcomes are strongly influenced by internal regulation, emotional safety, and reflective capacity. Learning environments are socio-cognitive systems where attention, participation, and decision-making are shaped by internal states as well as external structures.

Traditional Human Factors models offer limited tools for analysing these intrapersonal influences. SSHELL extends Human Factors applicability by recognising self-consciousness as system-relevant in educational contexts, enabling learning environments to be examined through a performance and regulation lens rather than solely an instructional one.

### ***Student–Teacher Meets as an Applied SSHELL-Aligned Tool***

Within educational settings, one practical application of Human Factors principles has been the structured use of Student–Teacher Meets (STMs). STMs are designed as one-to-one reflective dialogues that prioritise student self-awareness, emotional articulation, and shared regulation of the learning process.

Educators are trained to facilitate these interactions using Human Factors–informed techniques, enabling recognition of internal states that influence engagement and performance. In this sense, STMs function as an applied SSHELL-aligned intervention, making intrapersonal regulation visible and actionable within the education system.

### ***Operational Implications***

Operationally, SSHELL supports a shift from surface-level interventions towards self-regulation-informed system design. This includes training that strengthens reflective judgement, organisational cultures that encourage awareness rather than suppression of internal states, and system designs that treat human variability as a resource rather than a deviation.

By integrating internal regulation with external system analysis, SSHELL enhances the capacity of Human Factors practice to address complex, adaptive systems.

### ***Cross-Domain Relevance of the SSHELL Framework (EHF-Aligned)***

A key strength of the SSHELL framework is its applicability across domains with differing operational characteristics. By focusing on intrapersonal regulation rather than task-specific behaviour, SSHELL remains relevant wherever human judgement, decision-making, and emotional control influence system outcomes.

### ***Aviation: Formalising an Established Practice***

In aviation, self-conscious regulation has long been implicitly embedded within operational training and safety philosophy. Practices such as Crew Resource Management and Threat and Error Management emphasise self-monitoring, emotional control, and reflective judgement, particularly under conditions of high workload or uncertainty.

SSHELL formalises these practices by providing a conceptual structure that distinguishes between external system factors and internal regulatory processes. This distinction supports more precise analysis of performance variability, allowing investigators and trainers to differentiate between competence-related issues and regulation-related challenges. By making intrapersonal regulation explicit, SSHELL enhances both diagnostic clarity and training coherence without introducing new operational demands.

### ***Education: Extending Human Factors into a Developmental Domain***

Education represents an environment in which performance is shaped over time and is strongly influenced by internal cognitive and emotional processes. Unlike safety-critical domains where outcomes are immediate, educational outcomes depend on sustained attention, engagement, and self-regulation.

SSHELL enables educational environments to be examined as human performance systems, where internal regulation affects participation, decision-making, and resilience. By applying Human Factors principles to education through SSHELL, internal states such as anxiety, confidence, and reflective capacity can be recognised as system-relevant rather than peripheral. This supports the extension of **Human Factors thinking into education without imposing inappropriate safety-industry analogies**.

### ***Comparative Perspective***

Although aviation and education differ in immediacy, risk profile, and performance objectives, both depend on the human ability to regulate internal states within complex systems.

SSHELL accommodates these differences by operating at the level of regulation rather than execution. This cross-domain relevance aligns SSHELL with the expanding scope of Human Factors practice.

### ***Trainability, Recognition, and Measurement of Self-Consciousness (EHF-Aligned)***

A common concern when introducing intrapersonal constructs into system models is whether they are practical within operational timeframes. SSHELL addresses this by framing self-consciousness as a functional capability rather than a fixed trait.

#### ***Trainability***

Self-conscious regulation is already partially developed through existing training approaches, particularly in aviation. Scenario-based training, reflective debriefs, and decision-making exercises implicitly strengthen awareness of internal states and response modulation.

SSHELL consolidates these approaches by identifying self-consciousness as the underlying capability being trained. In education, trainability is supported through structured reflective interactions and guided dialogue, where learners and educators develop awareness of cognitive and emotional processes. SSHELL provides a framework for designing such training intentionally and systematically.

#### ***Recognition and Observability***

Although self-consciousness operates internally, it can be recognised through observable indicators. These include:

- Willingness to pause and reflect before action
- Ability to articulate internal states
- Emotional containment under pressure

- Adaptive rather than rigid decision-making

SSHELL enables these indicators to be interpreted consistently across contexts, supporting structured observation during training, supervision, and reflective practice.

### **Measurement Considerations**

At its current stage, SSHELL does not propose a single quantitative metric for self-consciousness. Instead, it supports multi-modal assessment approaches, including behavioural observation, structured reflection, and context-appropriate self-report measures.

The framework emphasises recognition and operational relevance prior to formal quantification. By establishing self-consciousness as a legitimate system dimension, SSHELL creates a foundation for future empirical research and measurement development.

### **Discussion and Future Directions (EHF-Aligned)**

The SSHELL framework responds to an increasing need within Human Factors to more explicitly account for the internal regulatory processes that influence human performance in complex systems. As operational environments become more cognitively demanding, socially embedded, and adaptive, performance variation is not always attributable to external system mismatches alone.

SSHELL does not seek to replace established Human Factors models. Instead, it extends the explanatory capability of the SHELL model by distinguishing between observable behaviour and intrapersonal regulation. This distinction enables a more nuanced understanding of why individuals operating within similar system conditions may demonstrate different performance outcomes.

A key strength of SSHELL lies in its conceptual discipline. The framework does not attempt premature quantification of self-consciousness, nor does it frame intrapersonal regulation as a universal explanation for performance failure. Rather, it offers a structured lens through which internal regulation can be recognised, discussed, and systematically incorporated into analysis, training, and system design.

- Future research directions include:
- Empirical exploration of SSHELL-informed diagnostic approaches
- Development of domain-specific indicators of self-conscious regulation
- Integration of SSHELL into existing Human Factors training methodologies
- Examination of SSHELL within emerging contexts such as AI-mediated work, hybrid human-machine systems, and educational environments

By establishing self-consciousness as a system-relevant dimension, SSHELL supports interdisciplinary collaboration across ergonomics, psychology, neuroscience, and education, contributing to the continued evolution of Human Factors theory and practice.

### **Conclusion**

The evolution of Human Factors has consistently reflected an expanding understanding of the human role within systems. From early ergonomic considerations to contemporary socio-technical analysis, each progression has sought to better align system design with human capability and limitation.

The SSHELL framework represents a further step in this progression. By explicitly integrating Self-consciousness as a core regulatory dimension, it enhances the diagnostic precision of the SHELL model while preserving its foundational strengths. SSHELL recognises humans not only as

interacting system components, but as self-regulating agents whose internal awareness, emotional control, and reflective judgement materially influence system outcomes.

Within aviation, SSHELL formalises regulatory processes that have long been implicitly addressed through training and operational practice. Within education, it provides a conceptual pathway for applying Human Factors principles to environments where internal regulation is central to performance and development. Across domains, SSHELL aligns with the increasing demand for adaptive, resilient, and human-centred systems.

In aligning Human Factors analysis with the realities of contemporary performance environments, SSHELL contributes to the discipline's ongoing task of adapting to the future while remaining grounded in established principles.

## References

- Dekker, S. (2014). *The Field Guide to Understanding 'Human Error'* (3rd ed.). Farnham, UK: Ashgate.
- Edwards, E. (1972). Man and machine: Systems for safety. In *Proceedings of the British Airline Pilots Association Technical Symposium*.
- Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37(1), 32–64.
- Flavell, J. H. (1979). Metacognition and cognitive monitoring. *American Psychologist*, 34(10), 906–911.
- Flin, R., O'Connor, P., & Crichton, M. (2008). *Safety at the Sharp End: A Guide to Non-Technical Skills*. Aldershot, UK: Ashgate.
- Gross, J. J. (1998). The emerging field of emotion regulation. *Review of General Psychology*, 2(3), 271–299.
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81–112.
- Hawkins, F. H. (1987). *Human Factors in Flight*. Aldershot, UK: Ashgate.
- Helmreich, R. L., Merritt, A. C., & Wilhelm, J. A. (1999). The evolution of Crew Resource Management training in commercial aviation. *International Journal of Aviation Psychology*, 9(1), 19–32.
- International Civil Aviation Organization (ICAO). (2018). *Human Factors Training Manual (Doc 9683)*. Montreal: ICAO.
- Kahneman, D. (2011). *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux.
- Norman, D. A. (1983). Some observations on mental models. In *Mental Models* (pp. 7–14). Hillsdale, NJ: Erlbaum.
- OECD. (2018). *The Future of Education and Skills: Education 2030*. Paris: OECD Publishing.
- Reason, J. (1997). *Managing the Risks of Organizational Accidents*. Aldershot, UK: Ashgate.
- Zimmerman, B. J. (2002). Becoming a self-regulated learner. *Theory Into Practice*, 41(2), 64–70.