Rethink Agile Scaling with Robotics Subsumption Architecture

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Abstract. Agile fosters speed, autonomy, and innovation at the team level, but organizations often struggle to preserve these strengths as they scale. Coordination overhead increases, decision-making slows, and the agility that once fueled success begins to erode. This paper introduces an approach to scaling by drawing on **Robotics Subsumption Architecture**, a model originally developed to build adaptive, autonomous robots. Building on the late **Mike Beedle**'s pioneering work in applying these robotics principles to organization design**,** we rethink how to design systems that grow without sacrificing local autonomy or real-time responsiveness. This approach offers scalable agility by embedding sensing, decision-making, and action into every layer—resulting in organizations that are resilient, decentralized, and capable of surviving today's VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) market.

Keywords: Agile Scaling, Business Agility, Enterprise Scrum, Subsumption Architecture

1 Introduction

Agile has transformed the way organizations deliver value. At the team level, Agile often brings remarkable speed, autonomy, and innovation. However, many organizations face significant challenges when scaling Agile across multiple teams. Coordination overhead increases, decision-making slows down, and the autonomy that made small teams successful often erodes.

How can organizations grow while preserving the agility that made them thrive? How can we scale without losing speed, autonomy, and responsiveness?
In this paper, we explore an innovative approach inspired by robotics: the ***Subsumption Architecture*** [1, 2]. Originally designed to create adaptive, autonomous robots, Subsumption offers powerful lessons for designing an organization's ecosystem. Building on the late ***Mike Beedle's*** pioneering work in applying these principles to organization design, we reimagine how to build organizations that are resilient, decentralized, and capable of dynamic, real-time adaptation—even as we grow.

2 Comparison with Established Agile Scaling Frameworks

While frameworks like SAFe [3], LeSS [4], and Scrum@Scale [5] aim to bring order and coordination to scaling Agile, they often rely on structured, top-down mechanisms that can hinder adaptability and autonomy. In contrast, Robotics Subsumption Architecture provides a fundamentally different paradigm for scaling agile. The following comparison highlights key differences:

Aspect	Established Agile Scaling Frameworks	Robotics Subsumption Agile Scaling Approach
Hierarchy & Structure	Typically, top-down, with structured layers for alignment and governance.	Subsumption-based and emergent; higher layers decide when to use or override lower layers.
Decision-Making	Often centralized at higher levels (e.g., Program or Portfolio).	Decentralized; lower layers act autonomously unless overridden by higher layers.
Adaptability	Change is managed through scheduled planning cycles (e.g., PI Planning, Sprint Reviews).	Real-time adaptation, as lower layers adjust continuously based on signals they receive.
Coordination & Dependencies	Dependencies managed via structured synchronization (e.g., SAFe ART Sync, LeSS Overall Planning).	Dependencies self-resolve through adaptive behavior—*Surfers* (domain experts) move across teams to align work.

3 Background

3.1 Robotics Subsumption Architecture

Developed by Prof. Rodney Brooks in the 1980s, **Subsumption Architecture** introduced a revolutionary architecture for building intelligent, adaptive systems. It was proposed in opposition to traditional symbolic AI, which attempted to guide behavior through internal models and symbolic mental representations of the world. It does this by decomposing the complete behavior into sub-behaviors. These sub-behaviors are organized into a hierarchy of layers. Each layer implements a particular level of behavioral competence, and higher levels are able to subsume lower levels (= integrate/combine lower levels to a more comprehensive whole) in order to create viable behavior. For example, a robot's lowest layer could be "Avoid Objects." The second layer would be "Wander Around," which runs beneath the third layer "Explore World." Because a robot must have the ability to "Avoid Objects" in order to "Wander Around" effectively, the Subsumption Architecture creates a system in which the higher layers utilize the lower-level competencies. The layers, which all receive sensor information, work in parallel and generate outputs. These outputs can be commands to actuators, or signals that suppress or inhibit other layers. [6]

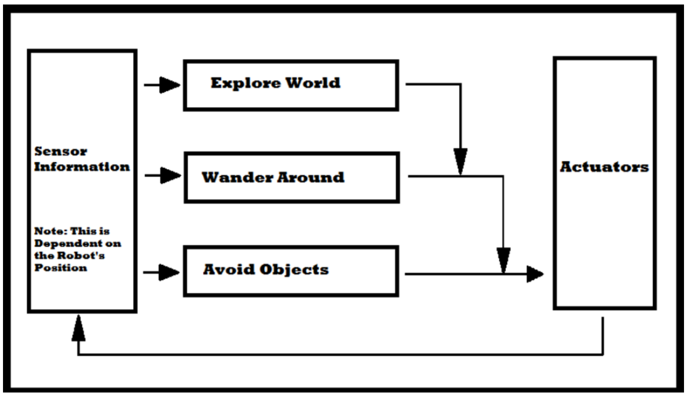

Fig. 1. Abstract representation of subsumption architecture, with the higher layers subsuming the roles of lower layers when the sensory information determines it. [6]

As shown in Figure 1, three core functions are

- **Subsumption Layers**: The behavior of exploring the world is divided into three hierarchical layers: Avoid Objects (lowest layer), Wander Around (middle layer), Explore World (highest layer). Higher layers subsume lower layers, meaning they can override their functions when necessary to achieve more complex behavior.
- **Sensor**: Continuously monitors the environment and feeds real-time signals to all layers simultaneously.
- **Actuators**: Execute actions based on which layers have been activated, ensuring appropriate responses to the environment.

It is this continuous interaction among these three functions—where layers react to sensor signals and trigger actuators based on defined conditions—that allows the system to behave in real time, without requiring centralized control or symbolic reasoning. As the robot moves through its environment, it continuously collects and integrates data from past interactions to adjust its behavior on the fly, identifying more effective paths and responses based on what it has encountered.

4 The Problem with Centralized Intelligence

Before Subsumption Architecture, robotics research pursued centralized intelligent systems that modeled the environment internally and attempted high-level strategic decision-making. However, these systems failed to perform reliably in dynamic, real-world environments. The complexity overwhelmed centralized models, and successes were limited to highly constrained tasks, such as developing a smart chess game [7]. Recognizing this failure, Rodney Brooks proposed a radical new approach: abandon complex internal models and focus on real-time environmental interaction through layered, autonomous behavior. This breakthrough fundamentally changed the trajectory of robotics and adaptive systems design.

5 Subsumption in Nature: The Human Body as an Analogy

Subsumption Architecture mirrors the natural organization of the human body.
Our bodies are composed of subsystems that function autonomously most of the time:

- The heart beats rhythmically without conscious involvement.
- The lungs maintain breathing automatically.
- Reflexes, like pulling away from heat, occur faster than conscious thought.

The body's **Sensor** system (nerves, receptors) constantly monitors the environment. Subsystems (layers) act based on this input, with minimal centralized intervention. When anomalies arise, **signals** like pain surface and escalate control to higher cognitive functions. **Actuators** (muscles, organs) carry out necessary actions. This biological model illustrates why **layered autonomy, real-time sensing, and dynamic suppression** are so powerful. Structuring organizations similarly — with continuous sensing, autonomous layers, and decentralized real-time action — enables adaptability, resilience, and growth.

6 Agile Scaling through Subsumption

Let us explore how to design for a customer-centric organization using subsumption principles, where customer segments serve as the basis for defining layers rather than a traditional functional hierarchy. Each layer represents a distinct level of abstraction—from products and services to customer segments, business units, and the overall company—while operating autonomously and building upon lower layers.

To operationalize this design, three key elements are introduced: **subsumption layers, signals, and surfers**, which together enable real-time sensing, coordination, and decision-making across the organization.

6.1 Building Blocks of Customer-Centric Organization

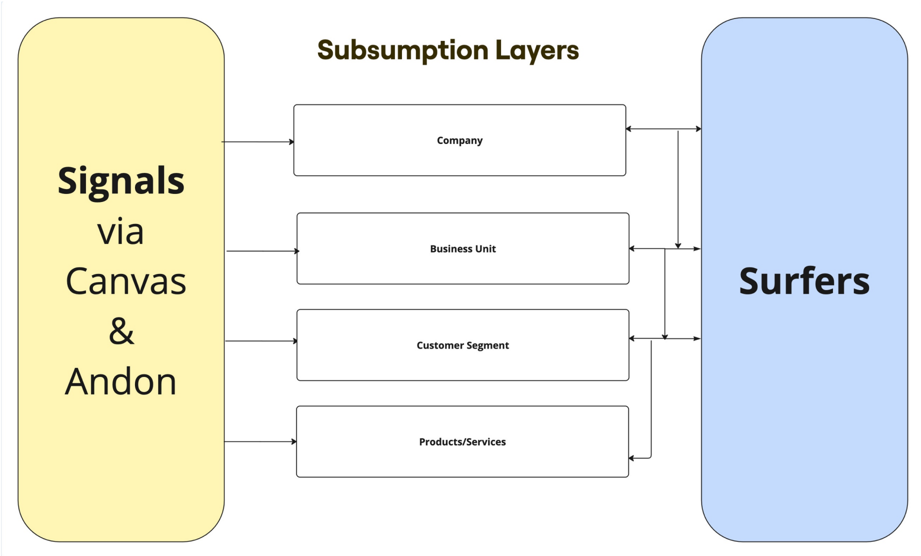

Fig. 2. Illustrating how Subsumption principles are applied to customer-centric organization

- **Subsumption Layers**: The organization is structured into hierarchical layers—Company (top), Business Unit, Customer Segment, and Products/Services (bottom). Each layer builds upon and can subsume the capabilities of lower layers, enabling alignment while preserving autonomy.
- **Signals via Canvas & Andon**: Analogous to sensors in robotics, business canvases and Andon-style signaling systems provide real-time visibility into organizational conditions, enabling timely and decentralized decision-making.
- **Surfers:** Surfers are domain experts who operate fluidly across layers, gathering real-time information, assessing conditions, and coordinating actions across teams. They enable decentralized yet synchronized decision-making without reliance on hierarchical command structures.
- **No Central Control**: Alignment emerges through the interaction of layers, signals, and surfers rather than through top-down control, allowing the organization to remain adaptive and responsive at scale.

This model enables organizations to embed agility across the system, supporting real-time responsiveness, autonomy, and alignment at scale.

6.2 Applying the Model: A Hypothetical eAuction Scenario

To illustrate how subsumption architecture can be applied to organizational design, consider a hypothetical eAuction platform. This example is not a real case study, but a simplified scenario used to demonstrate how a large organization can scale while maintaining autonomy and coherence.

eAuction is a digital marketplace for auctioning tickets across multiple industries, beginning with airline ticket auctions and later expanding into entertainment, sports, and fine arts. As the company grew rapidly, it needed an organizational ecosystem that could scale without losing the speed and autonomy that drove its early success.

To achieve this, eAuction applied principles from Robotics Subsumption Architecture to its organizational design. Rather than relying on centralized management, the company structured itself into layered, autonomous teams capable of responding to changing conditions such as market shifts, customer needs, or internal tensions.

6.3 Startup Phase: Building from the Bottom-Up

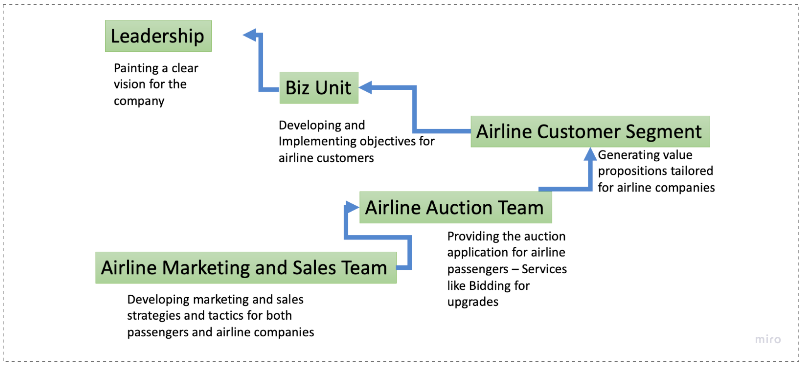

Fig. 3. eAuction's bottom-up approach of applying the subsumption architecture at the start-up-stage.

In its early stage, eAuction adopted a bottom-up approach, beginning with services tailored to the airline industry. Figure 3 illustrates how Subsumption Architecture was applied during this startup phase.

Starting at the foundation, the **Airline Marketing and Sales Team** focused on developing and executing marketing strategies for both passengers and airline partners. Building on this, the **Airline Auction Team** provided core auction capabilities, such as bidding services for ticket upgrades.

At the next level, the **Airline Customer Segment Team** focused on shaping value propositions for airline customers, ensuring that offerings aligned with their needs. Above this, the **Business Unit Team** defined and implemented broader business objectives for customers selling tickets.

These layers were anchored by the **Leadership Team**, which set the overall vision and direction for the company.

This bottom-up progression demonstrates how capabilities were built incrementally—each layer extending the one below it—while allowing teams to operate autonomously within their scope. Alignment emerged through the layering of responsibilities, rather than through centralized control.

6.4 Expansion Phase: Diversification and Structural Adaptation

eAuction has evolved from an airline-focused auction platform into a multi-segment marketplace. It now serves four primary customer segments: Airline Companies, Music Stars, Sports Leagues, and Artists. By organizing around customer segments, eAuction expands while maintaining autonomy and adaptability.

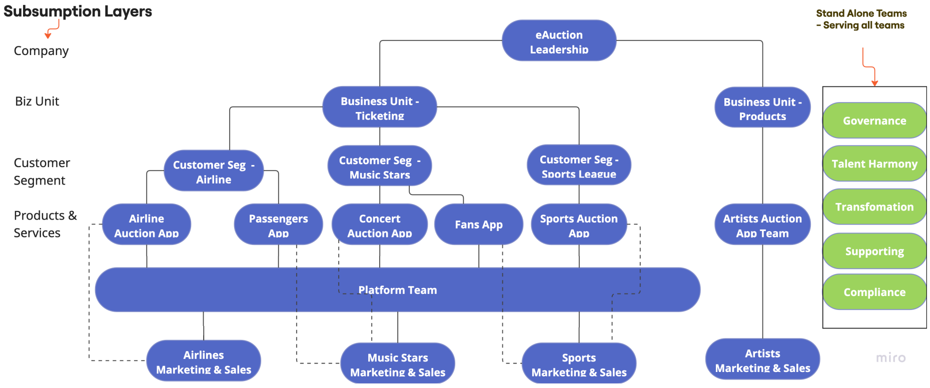

Fig. 4. Snapshot of eAuction's organizational structure at its current stage of growth.

Figure 4 illustrates how teams are structured based on who they serve. At the foundation, **Products & Services teams** support specific user groups—such as airlines, passengers, music stars, fans, sports leagues, and artists—focusing on delivering domain-specific capabilities.

These teams are grouped into **Customer Segment teams**. Each Customer Segment team serves a portfolio of value propositions while preserving team-level autonomy.

Above this, **Business Units** provide broader alignment. The **Ticketing Business Unit** brings together all ticket-based segments and is supported by a shared Platform Team that provides common capabilities. In contrast, the **Products Business Unit** (serving artists) operates separately, reflecting a different business model—auctioning artwork rather than tickets—which requires distinct applications and workflows.

At the top, **Leadership** sets overall direction, ensuring alignment across business units while allowing each layer to operate independently within its scope.

In addition, eAuction includes **standalone service teams**—such as Governance, Talent Harmony, Transformation, Supporting, and Compliance—that provide shared capabilities across the organization.

To support coordination and responsiveness across this decentralized structure, eAuction applies signaling mechanisms inspired by Robotics Subsumption Architecture. These mechanisms—Signals, Canvases, and Surfers—provide visibility into key conditions such as demand shifts, operational issues, and emerging risks.

Figure 4 represents a snapshot of this evolving system. As eAuction grows, teams can be added, regrouped, or separated based on who they serve—allowing the organization to scale while preserving autonomy and coherence.

7 Conclusion

This paper reimagines Agile scaling through the lens of Robotics Subsumption Architecture, shifting the focus from centralized coordination to layered autonomy and responsiveness. Using the hypothetical eAuction scenario, it illustrates how organizations can scale by structuring around customer segments, grouping teams based on who they serve, and allowing capabilities to emerge through layering.

A key insight is that scaling does not require increasing coordination overhead. Many scaling approaches introduce additional meetings, roles, and centralized decision-making to manage complexity. In contrast, the subsumption-inspired model enables organizations to respond to changing conditions through signaling mechanisms that provide visibility and trigger action within the appropriate layer. This reduces delays while preserving alignment.

By combining Subsumption Layers with Signals, Canvases, and Surfers, organizations can achieve a balance between autonomy and alignment. Teams operate independently within their scope, yet remain connected through shared visibility and selective intervention when needed.

While the eAuction example is illustrative, it demonstrates how this approach can support diversification, structural adaptation, and sustained responsiveness as organizations grow. Rather than enforcing alignment through control, alignment emerges from how the system is designed. As organizations continue to operate in increasingly dynamic environments, the ability to respond quickly without adding coordination burden becomes critical. The subsumption-based approach offers a viable alternative—one that enables scalable agility by design.

References

[1] R. Brooks, "A robust layered control system for a mobile robot," *IEEE Journal of Robotics and Automation,* p. 14–23, 1986.

[2] R. Brooks, "Asynchronous distributed control system for a mobile robot," in *SPIE Conference on Mobile Robots pp. 77–84*, 1986.

[3] Scaled Agile, Inc., "Scaled Agile Framework," 2025.

[4] The LeSS Company B.V., "The LeSS Framework," 2025.

[5] Sutherland, J., Scrum Inc., "The Scrum@Scale Guide," 2022.

[6] R. Brooks, "The Early History of the New AI," *Cambrian Intelligence,* pp. 8-12, 15-16, 1999.