

Rethink Large Scale Agile Organization with Robotics Subsumption Architecture

Sue Ryu¹ [0009-0000-0494-8462]

¹ Aha Autonomy, LLC, Woodland Park, NJ, USA
Sue.Ryu@AhaAutonomy.com

Abstract: Scaling is not simply about creating more of the same. As organizations grow, coordinating an increasing number of teams can introduce additional dependencies and coordination mechanisms that constrain autonomy. This paper proposes an alternative organizational systems design inspired by Brooks' Robotics Subsumption Architecture. Rather than prescribing a fixed organizational structure, the approach uses an organizing context to guide the composition of autonomous teams and capabilities into progressively broader organizational sub-units through subsumption. The resulting architecture aims to minimize dependencies requiring coordination across organizational boundaries while preserving local autonomy. An Organizational Sensing System (OSS) and Surfers provide adaptive mechanisms for responding to changing conditions and addressing interdependencies. A fictional eAuction example illustrates how customer segments can serve as the organizing context, enabling the organization to scale and readily incorporate new business opportunities without major restructuring of existing sub-units. The proposed approach reframes Agile scaling as the design of adaptive organizational systems that preserve autonomy and organizational coherence.

Keywords: Large Scale Agile Organization, Agile Scaling, Adaptive Organization, Business Agility, Enterprise Scrum, Robotics Subsumption Architecture

1 Introduction

Scaling is not simply about creating more of the same.

Many organizations scale through replication. Manufacturing companies build additional factories using established production systems, while franchise businesses expand by replicating proven operating models across new locations. Each unit largely functions as an independent whole. Scaling is achieved by repeating a successful model.

Large-scale Agile organizations face a fundamentally different challenge. A software product cannot be developed by simply replicating Agile teams. Instead, autonomous teams each contribute part of a larger product that must be continuously integrated with the work of other teams. As the number of teams grows, so do the dependencies between them [1,2]. The challenge is therefore not simply adding more teams,

but designing an organization in which autonomous teams collectively contribute to an integrated whole while preserving the autonomy that makes Agile effective.

Although Agile transformed how individual teams operate, organizations continue to rely largely on traditional hierarchical structures and coordination mechanisms to integrate their work. As organizations grow, coordination overhead can increase, decision-making can become more centralized, and team autonomy can diminish [3]. Most Agile scaling frameworks address these challenges by adding coordination mechanisms, planning events, and synchronization activities [4, 5]. While these can improve alignment, they primarily address how teams coordinate rather than how organizations are designed.

This paper approaches Agile scaling from an organizational systems design perspective. Rather than focusing primarily on coordinating dependencies among teams, it examines how closely related teams and capabilities can be grouped within shared organizational contexts, reducing dependencies that require coordination across organizational boundaries.

Nature offers examples of autonomous subsystems working together without centralized intelligence or comprehensive global planning. A similar engineering model can be found in Rodney Brooks' revolutionary Robotics Subsumption Architecture, in which decentralized behavioral layers interact directly with the environment, enabling real-time adaptive behavior without centralized control [6].

The origin of this work can be traced to a Lego game in an Enterprise Scrum class by the late Mike Beedle [7]. In the exercise, participants were asked to arrange business canvases to model the organization of a venture capital firm. Beedle did not explain in detail how this organizational arrangement related to Robotics Subsumption Architecture, but remarked that "all hierarchy is ideally in subsumption." The exercise, along with later discussions with Beedle, led the author to explore the connection between the organizational arrangement and Subsumption Architecture and, following his passing, to continue developing that connection into a more explicit approach to organizational systems design.

Building on this exploration, this paper proposes an organizational systems design approach for large-scale Agile organizations in which autonomous organizational units contribute to progressively larger integrated systems while preserving their autonomy. The fictional eAuction example was developed to illustrate how the approach could be implemented in an organization.

2 Background Robotics Subsumption Architecture

In the mid-1980s, Rodney Brooks challenged the prevailing paradigm in artificial intelligence and robotics. At the time, intelligent systems were typically designed around centralized control, comprehensive world models, and global planning. A robot was expected to construct an internal representation of its environment, determine an appropriate course of action, and then execute that plan. While effective in controlled

environments, these systems were often computationally expensive, slow to respond, and difficult to adapt to dynamic, unpredictable conditions.

Brooks proposed an alternative known as the Subsumption Architecture, a layered control architecture that eliminated the need for centralized intelligence and comprehensive world models. Instead of relying on a single controller, the architecture consists of multiple autonomous behavioral layers that interact directly with the environment. Sensors detect environmental conditions and provide inputs to the behavioral layers, which process these inputs and generate outputs that control the robot's actuators. Actuators translate these outputs into physical actions, such as movement. Each layer operates autonomously, enabling the robot to respond to changing conditions without relying on centralized control [6].

The layers are organized hierarchically, with higher layers capable of influencing lower layers through suppression or inhibition when appropriate. Rather than replacing lower-level behaviors, higher layers augment them by introducing additional capabilities while preserving the autonomy and responsiveness of the underlying layers. As new layers are added, increasingly sophisticated system behavior emerges without re-designing the existing architecture [6].

A fundamental principle of the Subsumption Architecture is that coherent system behavior emerges through the interaction of autonomous components rather than through centralized control. Intelligence is distributed across behavioral layers, each responding to local environmental conditions in real time. This decentralized approach enables systems to remain adaptive, robust, and responsive in complex environments.

Although originally developed for autonomous robots, the architectural principles underlying the Subsumption Architecture extend beyond robotics. The combination of autonomous units, layered organization, local decision-making, decentralized interaction, and emergent system behavior provides a compelling engineering model for designing adaptive systems. These principles form the foundation for the organizational systems design presented in this paper.

3 Organizational Systems Design Through Subsumption

The proposed organizational design consists of autonomous sub-units that operate within their own contexts while contributing to a larger organizational system. Rather than relying on centralized control, the organization maintains coherence through subsumption, shared information, and adaptive coordination.

Teams and sub-units respond to signals about customer needs, market conditions, technology, and operations. They make decisions locally whenever possible, while Surfers help address concerns that require coordination.

3.1 Design Principles

Organizing Context

The organizing context defines the primary basis for grouping related teams and capabilities into organizational sub-units. Its selection should reflect how the organization creates and delivers value, while considering the nature of its business, customer needs, product maturity, and operating environment.

The selection of an organizing context can be grounded in established management and organizational research. Peter Drucker emphasized that the purpose of a business is to create customers, placing customer needs and value creation at the center of business strategy [8]. Clayton Christensen demonstrated how established organizations can struggle to pursue emerging markets when new opportunities require different value propositions and operating priorities [9]. Conway's Law further suggests that organizational communication structures influence the systems organizations design, highlighting the importance of grouping closely related teams and capabilities to facilitate communication and collaboration [10].

Drawing on these perspectives, this paper proposes customer segments as the organizing context for the eAuction example, particularly because the organization is exploring emerging markets with potentially distinct customer needs and value propositions. Organizing around customer segments allows related teams and capabilities to work within a shared customer context while providing the autonomy needed to develop and adapt their offerings.

Customer segments work well as an organizing context when exploring emerging markets with different customer needs and value propositions. However, other organizing contexts should be considered based on organizational needs, such as the maturity of products and services, geographic markets, or product lines. A comprehensive examination of how to select an organizing context is beyond the scope of this paper.

Subsumption

Once the organizing context has been established, related teams and capabilities are progressively composed into organizational sub-units. Each sub-unit operates within its own context, has responsibilities appropriate to that context, and retains the autonomy to make decisions within it.

Through subsumption, related sub-units are progressively composed into broader organizational layers. Each broader layer establishes a larger context with its own responsibilities while preserving the autonomy of the sub-units within it. In this way, responsibilities and decisions can remain as local as possible while broader concerns are addressed at the layer where they become relevant.

Unlike traditional hierarchical decomposition, subsumption focuses on composing related teams and capabilities into larger organizational wholes rather than partitioning responsibilities into smaller units. The resulting layers represent progressively broader

organizational contexts and responsibilities, rather than levels of managerial authority and control.

3.2 Adaptive Organizational Operation

The Organizational Sensing System (OSS) makes organizational conditions visible through team canvases, shared information, signals, and Andon-like mechanisms. Teams and Surfers use this information to recognize changing conditions and respond.

Teams interpret signals and act within their own contexts whenever possible. Grouping closely related teams through subsumption allows many dependencies and concerns to be addressed locally.

In the proposed organizational application of subsumption, broader organizational layers establish the context, responsibilities, and constraints within which their sub-units operate. When broader organizational concerns arise, intervention may be necessary to coordinate the responses of affected sub-units. Such intervention is exercised through organizational decision authority rather than the direct suppression of outputs found in robotic systems. This allows teams to retain autonomy in their normal operations while enabling coordinated responses when broader concerns arise.

Surfers provide adaptive stewardship by monitoring signals, recognizing patterns and interdependencies, facilitating collaboration among affected teams and sub-units, and ensuring that necessary actions are carried through. They consult appropriate subsumption layers and exercise bounded decision authority when needed. Teams remain responsible for carrying out the work.

Together, the subsumption structure, OSS, autonomous teams, and Surfers enable the organization to respond to changing conditions while preserving autonomy and organizational coherence.

	Robotics	Large Scale Organization Systems Design
Sensing	Sensors detect environmental conditions and provide inputs to all layers.	The OSS makes organizational conditions visible through canvases, shared information, signals, and Andon-like mechanisms to all layers.
Subsumption Layers	Layers process sensor inputs; higher layers can suppress or inhibit lower-layer outputs.	Teams within subsumption layers interpret information from the OSS and respond within their contexts. When broader organizational concerns arise, appropriate decision-makers may constrain, suspend, or redirect activities of sub-units within that context. This enables local autonomy while maintaining organizational coherence.
Acting	Actuators execute physical actions.	Teams make decisions and carry out actions within their contexts.

Adaptive Intervention	Higher layers can suppress or redirect lower-layer outputs.	Surfers facilitate responses across organizational contexts and exercise bounded decision authority when needed.
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Table 1 Adapting Robotics Subsumption Architecture to Organizational Systems Design

3.3 Responsibilities and Decision Authority

An organizational system composed of autonomous teams and sub-units requires a clear understanding of responsibilities and decision authority. In the proposed design, authority is contextual rather than positional. Decision authority is determined by the organizational context and the responsibilities associated with teams, subsumption layers, and Surfers, rather than by an individual's position in a managerial hierarchy.

Teams have the authority to make decisions and take action within their own contexts and responsibilities. They respond to organizational signals, manage their local dependencies, and determine how best to carry out their work. Local autonomy remains the default, allowing teams to respond rapidly without unnecessary escalation or centralized approval.

Subsumption layers represent progressively broader organizational contexts, each responsible for the larger whole composed of its sub-units. For example, as illustrated in the eAuction example in Section 4, a Customer Segment layer is responsible for the portfolio of products and services serving that customer segment, while individual Products & Services teams are responsible for developing and delivering the actual products and services. Decision authority is therefore associated with the responsibilities of that layer and the scope of its organizational context. When broader organizational concerns require intervention, the appropriate decision-makers, working within that broader context, may constrain, suspend, or redirect activities of these sub-units.

Surfers are stewards accountable for specific organizational responsibilities, with bounded decision authority within their areas of stewardship. When a signal reveals an interdependency or concern that cannot be adequately addressed within a team's local context, the relevant Surfer engages the affected teams and the appropriate subsumption layer. Through consultation, the Surfer develops an understanding of the broader context, the implications for affected sub-units, and the actions required. The Surfer may then exercise decision authority within the defined scope of stewardship, while the teams retain responsibility for determining how to carry out the necessary work.

	Responsibilities and Decision Authority
Teams	Decide and act autonomously within their contexts and responsibilities.
Subsumption Layers	Establish broader organizational contexts, responsibilities, priorities, and constraints. Broader-layer concerns may take precedence over local priorities when necessary.
Surfers	Exercise bounded authority within their stewardship areas after consulting affected teams and relevant layers.

Table 2 Responsibilities and Decision Authority

Decisions should therefore be made at the narrowest organizational context capable of adequately addressing the concern. When a concern extends beyond that context, the relevant Surfer engages the broader organizational layer and affected sub-units. The broader the impact, the broader the organizational context that must be considered. This does not imply that decisions must move upward through a chain of managerial approvals. Rather, decision authority follows the responsibilities and contexts affected by the situation.

This separation of responsibilities allows teams to remain autonomous in their day-to-day work while enabling the organization to respond coherently when broader concerns arise. Subsumption provides the organizational contexts within which responsibilities and constraints are established, while Surfers provide the adaptive decision-making capability needed to address concerns across those contexts. Together, they enable decentralized decision-making without sacrificing organizational coherence.

4 Applying the Organizational Systems Design: The eAuction Example

To illustrate how the proposed organizational systems design approach can be applied, consider the fictional company eAuction. This example is not a real case study, but a simplified scenario used to illustrate how an Agile organization can scale while preserving autonomy and organizational coherence.

eAuction is a digital marketplace that enables customers to auction products across multiple industries. Initially focused on airline ticket auctions, the company later expands into entertainment and fine arts. As the business grows, it requires an organizational system that can scale without sacrificing the autonomy, adaptability, and responsiveness that fueled its early success.

4.1 Startup Phase

eAuction initially operates like a startup, with a single cross-functional team exploring whether there is a viable need for its online auction service. The team focuses on the airline industry as its initial market. It includes marketing and sales, software development, and business capabilities working together to understand the needs of airline customers and passengers and validate viable value propositions.

As the business grows and its understanding of the airline market becomes clearer, the startup team evolves into specialized but autonomous teams. The Airline Marketing & Sales Team engages with the market and customers, gathering feedback and supporting positioning, messaging, campaigns, and sales. The Airline Auction Team develops and delivers auction applications, such as seat-upgrade bidding, that help airline customers generate additional revenue. The Airline Customer Segment Team focuses on

the portfolio of value propositions serving airline customers and passengers. These teams work together within the Airline Customer Segment, guided by the eAuction Company Team.

Figure 1 illustrates this evolution and the responsibilities of each team. The descriptions beneath the teams highlight their respective contributions and show how initially integrated startup capabilities become autonomous organizational sub-units as eAuction grows.

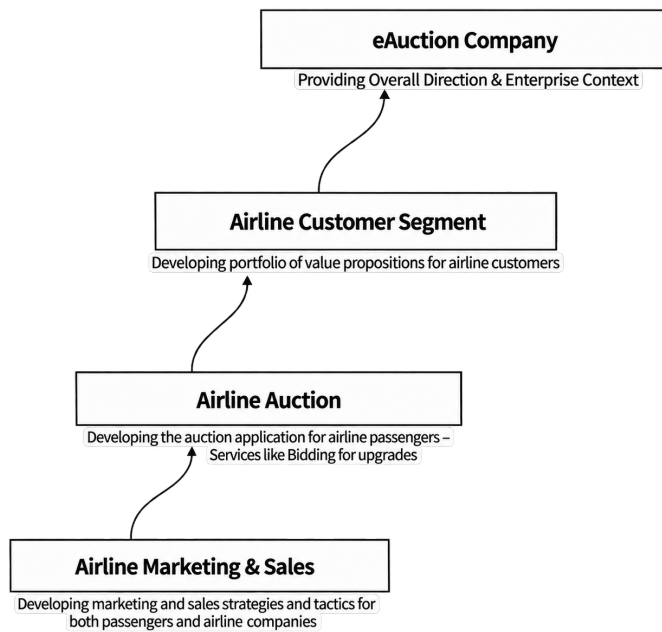


Figure 1 eAuction organizational architecture during the startup phase.

4.2 Scaling Through Additional Customer Segments

Drawing on the customer-oriented perspectives of Peter Drucker and Clayton Christensen discussed in Section 3.1, eAuction selects customer segment as its organizing context for scaling. As the organization grows, it creates organizational sub-units around customer segments and progressively composes them into broader organizational entities through subsumption. Each layer encompasses a portfolio of the sub-units below it and incorporates the additional capabilities and services needed within its broader organizational context.

Products & Services teams develop and deliver products and services that fulfill the value propositions for their customer segment, working closely with marketing and sales teams. The Customer Segment Team manages the portfolio of value propositions

and identifies additional value the organization could offer to customers in that segment.

As eAuction expands from Airline into Entertainment, the two Customer Segments are composed within the Ticketing Business Unit because they share similar ticket-based auction capabilities. The Ticketing Business Unit Team manages the portfolio of these Customer Segments and addresses concerns shared across them. A Shared Platform Team provides common auction capabilities to both segments, reducing duplication while allowing each to operate autonomously.

When eAuction enters the Fine Arts market, however, it encounters substantially different customer needs and business requirements. Rather than placing Fine Arts within Ticketing, eAuction establishes a separate Products Business Unit. This Business Unit encompasses the Fine Arts Customer Segment and provides the broader capabilities appropriate to its distinct business model.

At the Company layer, the eAuction Company Team manages the portfolio of Business Units and addresses enterprise-wide concerns. The Ticketing and Products Business Units remain autonomous within their respective contexts while contributing to the broader company.

In this way, eAuction scales through a progression of subsumption layers: Products & Services → Customer Segment → Business Unit → Company. At each layer, related organizational sub-units are composed into a broader portfolio, with additional capabilities and services provided according to the needs of that organizational context. This approach allows the organization to expand while keeping closely related dependencies within the appropriate sub-units and preserving their autonomy.

Figure 2 illustrates the resulting architecture. The dashed boundaries represent organizational sub-units, or instances, composed within progressively larger subsumption layers.

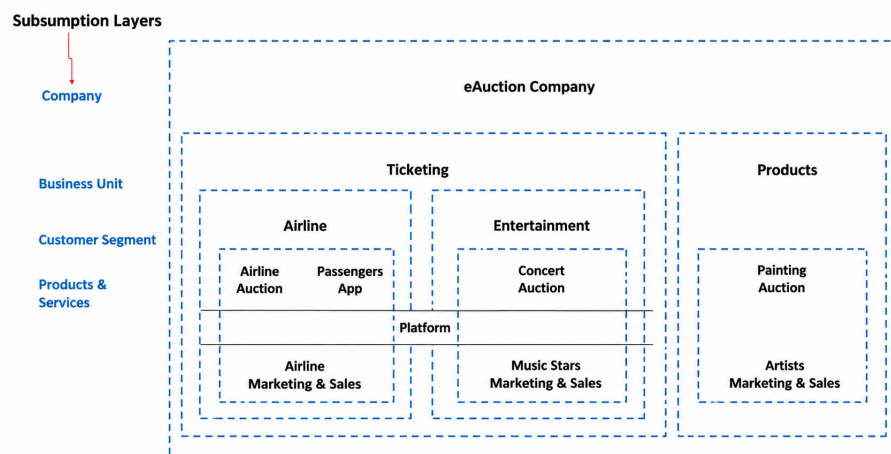


Figure 2 Expanded eAuction organizational architecture for Airline, Entertainment, and Fine Arts.

4.3 Adaptive Organizational Operation

In eAuction, the Organizational Sensing System (OSS) is implemented through team canvases, organizational signals, and Andon-style mechanisms. Each team maintains a canvas that visualizes its objectives, current activities, and other key information, providing transparency across the organization. Teams set signals for conditions relevant to their work and subscribe to signals from other teams to be notified when those conditions arise. Andon-style mechanisms allow teams to raise concerns requiring immediate attention or intervention. Together, these mechanisms make organizational conditions visible, enabling teams and Surfers to interpret and respond to them within their respective contexts and responsibilities.

Teams interpret and respond to signals within their own contexts whenever possible. When conditions affect broader organizational concerns, the appropriate decision-makers may intervene within their scope of authority to constrain, suspend, or redirect activities. Surfers monitor signals within their areas of stewardship, facilitate collaboration among affected teams and sub-units, consult the appropriate subsumption layers, and ensure that necessary actions are initiated and carried through.

Adapting to a New Market Opportunity

For example, a sharp increase in energy prices and growing demand for EV charging capacity may create an opportunity to explore auction-based allocation of charging reservations. Recognizing this emerging opportunity through organizational signals, eAuction initiates an experiment to apply its auction capabilities to EV charging reservations.

A small cross-functional team explores the new market, develops an experimental service, and validates customer needs and potential value propositions without disrupting existing business operations. Surfers facilitate collaboration and address dependencies across organizational boundaries when needed.

If the experiment proves viable, eAuction can establish a new Energy Customer Segment rather than embedding the emerging business within an existing customer segment. Because the energy market involves substantially different customers, regulations, and operational capabilities, the new segment may be composed into a separate Energy Business Unit. Through subsumption, these new organizational sub-units can be readily incorporated into the broader company without requiring major restructuring of existing organizational sub-units, allowing existing teams to continue operating autonomously.

Responding to an Operational Emergency

Another example illustrates how Surfers intervene when existing capabilities are insufficient to address an unexpected operational condition. eAuction's Airline Customer Segment experiences a sudden increase in suspicious bidding activity, triggering fraud alerts through the Organizational Sensing System (OSS). Normally, such conditions could be handled automatically by the bidding application. However, suppose the application does not yet have the capability to suspend suspicious bidding automatically.

When a fraud-related signal reveals a risk that cannot be adequately addressed within the Airline Auction Team's context, the relevant Surfer engages the affected teams and consults the appropriate organizational layer. A decision may then be made, within the applicable decision authority, to suspend bidding or impose additional restrictions until the risk is addressed. The Airline Auction Team implements the necessary changes while retaining responsibility for its product and normal operations.

This example illustrates how Surfers provide adaptive intervention when existing organizational or technical mechanisms cannot adequately respond to an unexpected condition. The teams remain responsible for carrying out the work, while the Surfer provides the stewardship needed to coordinate an effective response.

Scenario	Type of Adaptation	What It Illustrates
Energy-market opportunity	Strategic and structural adaptation	Experimentation with a new business opportunity and evolution of the organizational architecture through subsumption.
Fraud detection in Airline auctions	Operational adaptation	Higher-layer suppression of normal bidding activity and Surfer intervention when existing capabilities are insufficient.

Table 3 Two Dimensions of Organizational Adaptability

Through transparency, organizational signals, and Surfer stewardship, autonomous teams can coordinate their responses to operational disruptions and emerging opportunities. The organization can adapt not only by changing its behavior within the existing structure, but also by evolving the structure itself, incorporating new capabilities and organizational sub-units while preserving the autonomy of existing teams.

The eAuction example illustrates how the proposed organizational systems design can be applied as an organization grows, from its initial startup structure to a more complex enterprise. Although hypothetical, the example provides a basis for examining how the proposed approach might operate in practice.

5 Conclusion

The proposed organizational systems design shifts the focus of Agile scaling from coordinating teams to designing organizations that enable autonomy and coherence. Inspired by Brooks' Robotics Subsumption Architecture, the approach provides design principles for composing autonomous organizational sub-units into adaptive organizational systems.

Rather than prescribing a fixed structure, the approach derives organizational architecture from an organization's organizing context. By grouping closely related teams and capabilities and progressively composing them through subsumption, the design minimizes dependencies requiring coordination across organizational boundaries while preserving local autonomy. Organizational design is therefore an evolutionary process in which the organizing context and resulting architecture are continuously evaluated and refined as the organization scales.

Adaptive operation is enabled through the Organizational Sensing System (OSS) and Surfer stewardship. Together, these mechanisms allow autonomous teams and organizational sub-units to respond to changing conditions, address interdependencies, and adapt their behavior without relying on centralized coordination. The organizational architecture itself can also easily adapt to emerging opportunities and changing conditions.

Elements of this approach were explored in practice by Mike Beedle through his Enterprise Scrum work. However, the more comprehensive application of Subsumption Architecture to organizational systems design, as illustrated through the eAuction example, remains to be explored in practice. Future work should apply the proposed design in real organizational settings, evaluate its effectiveness, and explore how different organizing contexts produce different organizational architectures.

The future of Agile scaling lies not in coordinating more teams, but in designing adaptive organizational systems that preserve autonomy while enabling organizational coherence.

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