

ICAS: The Intelligent Complex Adaptive System

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As we begin to understand and hopefully anticipate the behavior of the current and future environment, it becomes clear that neither the classic bureaucratic nor the current popular flat organization will provide the unity, complexity and selectivity necessary for survival. A different approach to design is needed to create an organizational system that can enter into a symbiotic relationship with other organizations within its enterprise and with the external environment while retaining its own unity of purpose and selectivity of incoming threats and opportunities, i.e., turning the *living system* metaphor into a reality. This organization would build on the currently anticipated knowledge organization to become a living system composed of living subsystems that combine and interact to provide the capabilities of an advanced, intelligent techno-sociological adaptive enterprise. The system we propose can best be described as ICAS, an intelligent complex adaptive system.

ICAS is a conceptual model developed to bring out the most important capabilities necessary to live and contribute in an unpredictable, dynamic and complex society. As an idealization, it consists of pure forms and perfect structures, neither of which is found in practice. The variation in human experience and behavior, together with the practical demands of the workforce and natural difficulties in communication create a reality that is often far from ideal. Nevertheless, new concepts, perceptions, relationships and communications are essential if our organizations are to keep up with the pace, direction and demands of society.

Definitions and Assumptions

The term complex system means a system that can take on a very large number of states. A state is a specific instance of a set of elements and the relationships among them. In ICAS the components of the system (organization) are individuals, groups of workers or subsystems (both human and non-human) of the organization. ICAS, then, is composed of a large number of individuals, groups, and human subsystems with the capability to make many local decisions and strive for specific end states or goals. These components build many relationships both within the organization and external to the organization's boundaries that become highly complex and dynamic. Together, these relationships and their constituents form the organization and its enterprise. The word *adaptive* implies that the organization and its subcomponents are capable of studying and analyzing the environment and taking actions that adjust the organization to the forces in that environment to fulfill local and higher level goals.

Complex adaptive systems (organizations), then, are composed of a large number of self-organizing components that seek to maximize their own goals but operate according to rules and in the context of relationships with other components and the external world. In an intelligent complex adaptive system the actors are people. The

organization may be composed of hierarchical levels of workers, which can take the form of teams, divisions or other structures that have common bonds. While the workers are empowered to self-organize, they are not independent from the corporate hierarchy. Along with the increased freedom to organize and act at the lower levels of the system comes a responsibility for awareness of local situations, organizational goals and values and the ongoing activities and available knowledge throughout the rest of the organization. By providing workers the encouragement to think and act on their own, the ICAS will manifest itself through eight characteristics essential for survival and growth in the previously described external landscape. *Organizational intelligence* is needed to provide the advantages of innovation, learning, adaptation and quick-response to new and trying situations. In further discussions, we use the terms “ICAS”, “system”, and “organization” interchangeably.

Though complex adaptive systems have been formally studied for several decades, current understanding of them can best be described as “work in process.” Nevertheless, numerous examples of them include ant colonies, cities, the brain, the immune system, ecosystems, computer models and, of course, organizations. There are some basic properties common to many complex adaptive systems. Examples are some level of self-organization, non-linearity, aggregation, diversity and flow. See Holland, Battram, and/or Stacy for particularly lucid explanations. For more in-depth analyses of complex systems see Kauffman, Axelrod, Morowitz and Singer, and Axelrod and Cohen.¹

One finding in the research on complex adaptive systems is that they have the ability to exist and operate in a state that is between pure stability and complete instability in a region that contains both stability and instability. In this mode, the organization is able to be innovative and creative, while concomitantly keeping its identity and cohesion, (Stacy, 2000). According to Stacy, this state is achieved only when each of three parameters: information/energy flow, connectivity among workers, and diversity of perspectives and ideas among workers, have the right levels. What these levels should be for any given organization and situation is a matter for research and trial and error to determine. Certainly they are all sensitive to culture, situational context and external forces. Note that if any (or all) of these parameters become too high, the organization may be pushed into saturation, confusion or chaos – leading to an inability to respond and adapt to the environment. If all of the parameters are low, for example if the information flow among workers is low, people work in isolation and in a classical bureaucracy everyone will follow the boss’s orders without question. The result would be an organization optimized for productivity in a stable, indeterministic environment. Clearly, such an organization will not survive long in a changing, complex one.

Certain assumptions were made in developing the ICAS model discussed in this book. One assumption is that nature, with her millions of years of experience through evolution, provides us with insights to understand the behavior of people working in complex organizations. Another source of insight is consciousness and how the brain/mind works. Some characteristics of the human mind are helpful for understanding knowledge organizations in more than superficial ways. For example, a key to success in

living systems is how efficiently and effectively they handle information both within their boundaries and in their interaction with the environment². Similar capabilities are needed by modern complex organizations.

The ICAS Model

Organizations take inputs from their environment, transform those inputs into higher-value outputs and provide them to customers and stakeholders. Organizations solve problems (or take on opportunities) by creating options using internal and external resources in efficient and effective ways that create added value above and beyond the value of the inputs. Briefly, the organization solves problems (or takes on opportunities) that create options for action that then produce some internal or external value. Although they do this through available resources – people, ideas, technology, funds, facilities, etc. -- as we move from the manufacturing to the information to the complexity age most valuable resource becomes knowledge. While there are a great many definitions of knowledge, we take it to be the capacity to create and add value by taking effective action in varied and uncertain situations. We use the term capacity to mean both potential and actual. This continuous ability to take effective action requires judgment, experience, context, insight, the right information, and the application of analysis and logic. Both understanding and meanings become the requisite objectives before taking effective action. This ability to create value through effective action, whether for employees, investors, customers or other stakeholders, will be *the driving force* behind survival and growth. When the challenge is not routine the organization must be creative and generate innovative ways of solving problems and developing new opportunities. When facing non-routine situations, the organization, through its people working together or independently, must make decisions and take actions that produce their intended results. Making good decisions and taking effective actions each require knowledge; information alone is not up to the challenge when uncertainty, ambiguity or complexity dominate the landscape.

While this paradigm is easy to describe, it becomes very complex and challenging in the real world, particularly when things are moving quickly, problems are not well understood, there are many opinions and options, and a successful outcome is dependent on uncertain events. Understanding and successfully applying the four processes of creating new ideas, solving messy problems, making decisions and taking action to achieve a desired result is the major challenge to all organizations, including the ICAS. The processes themselves become core competencies that every intelligent organization must master.

The intelligent complex adaptive systems (ICAS) may need to be highly diversified or superbly coherent, depending on its mission and purpose and on the environment in which it lives. It will need to exhibit a unity of purpose and a coherence of action while being highly selective and sensitive to external threats and opportunities. An ICAS may have to rapidly bring together diverse knowledge located anywhere in (or beyond) the organization to solve problems and take advantage of opportunities.

Since only people can make decisions and take actions in a highly uncertain environment, there will be increasing emphasis on individual worker competency and freedom in terms of learning, making decisions, and taking actions in given areas of responsibility leveraged through multiple and effective networks that provide sources of knowledge, experience and insights from others. These dynamic networks will represent the critical infrastructure of the next generation knowledge-based organization. Made available by increased bandwidth and processing power of both silicon and biotechnology, they offer the opportunity for virtual information and knowledge support systems that connect data, information and people through virtual communities, knowledge repositories and knowledge portals. The foundation and grounding of future firms will be strengthened through a common set of strong, stable values held by all employees. Such values not only provide a framework that enhances empowerment but also motivates and strengthens the self-confidence of the workforce, thereby magnifying the effectiveness of the self-organized teams within the ICAS. To survive and successfully compete in the future world, these organizations will need to possess a number of emergent characteristics that taken together result in resilience, agility, adaptivity and learning, all well-known traits of survival.

Emergent Characteristics

As organizations change and take on new forms, they often do so through the creation and development of what complex systems theorists call emergent characteristics. Mills suggests three criteria for emergence:

“First, an emergent character of a whole is not the sum of the characters of its parts; second, an emergent character is of a type totally different from the character types of the constituents; third, emergent characters are not deducible or predictable from the behaviors of the constituents investigated separately”.
(Auyang, 1998, p. 174)

The sources of emergent properties are both structural and relational. Auyang notes “Emergent characters mostly belong to the structural aspect of systems and stem mainly from the organization of their constituents” (Auyang, 1998, p. 176), whereas Holland writes “Emergence is above all a product of coupled, context-dependent interaction. Technically these interactions, and the resulting system, are *nonlinear*: The behavior of the overall system *cannot* be obtained by *summing* the behaviors of its constituent parts. ... However, we can reduce the behavior of the whole to the lawful behavior of its parts, *if* we take the nonlinear interactions into account.” (Holland, 1998, pp. 121-2) Ingber, in investigating biological design principles that guide self-organization and emergence, extends the normal complexity-based approaches that focus on nodes, connections, and resultant pattern formation to include the importance of architecture, mechanics and structure in the evolution of biological forms. (Ingber, 2000, pp. 269-280) Human organizations abound with all of these phenomena. When emotions run high, the smallest event can create an explosion of feelings and action. Even routine human behavior is too complex to reduce to single causes. Relations create

interdependencies that may result in completely new and unique ideas or actions, results that can rarely be traced back to any point of origin in the interaction that produced them.

Some examples of emergent phenomena suggested by Coveney and Highfield are: life is an emergent property arising from physicochemical systems organizing and interacting in certain ways; a human being is an emergent property of huge numbers of cells; a city is an emergent property of thousands or millions of humans; and a company is more than the sum of its technology, real estate and people (Coveney and Highfield, 1995, p. 330).

The eight emergent characteristics are shown in Figure One to highlight their relationships. The ICAS is in many ways a biological system, as it must be to survive in a rapidly changing, nonlinear, complex, dynamic and uncertain world. These eight characteristics help provide the internal capability to deal with the future environment. We will briefly address each of them here in turn: Organizational Intelligence, Shared Purpose, Selectivity, Optimum Complexity, Permeable Boundaries, Knowledge Centric, Flow and Multi-Dimensionality.

The Eight Emergent Characteristics of ICAS

Intelligence, according to Webster, is the capacity for reasoning and understanding or an aptitude for grasping truths. (Webster, 1996, p. 739) When applied to organizations, Wiig broadens this view of intelligence and considers it the ability of a person to think, reason, understand and act. He further considers intelligence as applying to organizations and includes the capabilities to innovate, acquire knowledge and apply that knowledge to relevant situations. (Wiig, 1993, p. 84) From an organizational viewpoint, both employees and their organization can exhibit intelligent behavior.

Pinchot and Pinchot describe the intelligent organization as one that can face many competitors simultaneously and deal effectively with all of them while attending to all the details and supporting competencies that add up to cost-effective, superior performance. Further, “the quality of relationships between members of the organization is a strategic issue that determines the very fabric of the organization.” (Pinchot & Pinchot, 1993, p. 70)

As a working concept for the ICAS model, *organizational intelligence* is taken to be the ability of an organization to perceive, interpret and respond to its environment in a manner that simultaneously meets its organizational goals while satisfying its stakeholders, that is, its employees, customers, investors, community and environment. Organizational intelligence is a descriptive term that indicates the measure of the organization’s (and its workforce’s) capacity to exhibit intelligent behavior.

Unity and Shared Purpose represents the ability of the ICAS organization to integrate and mobilize resources to (1) provide a continuous line of focus and attention and (2) pull together the relevant parts of the organization when and where they are needed. For an organization to work intelligently, it must be able to coordinate and unify

its relevant resources to gain maximum situational understanding, knowledge and concentration of power to act and to respond. Faced with a large number of threats and opportunities and the potential need for quick reaction, the ICAS will have systems that continuously reach into, and maintain, continuous two-way communication with a large number of relatively independent subsystems. According to complexity research (Stacey, 1996), these subsystems of agents should organize themselves to maximize their learning, innovation and knowledge, that is, their ability to take effective action at the local point of stakeholder interface.

Optimum complexity is a new concept in organizational theory. First consider the concept of complexity as it applies to organizations. Complexity is most simply interpreted as being a measure of the number of states (elements and/or their relationships) in a system. While useful in many applications, there are difficulties with this interpretation when considering organizations. It is not the number of possible states -- either in the organization or in its external environment -- that need concern an organization. It is the *number of possible states that make a difference to the organization* that are important. Of the almost infinite number of states of information, material and energy that impinge upon every organization, only a few of them are meaningful and make a difference. The ability to recognize this difference can become a useful way for the ICAS to reduce its own internal complexity as well as the impact of the external complexity in its environment. When done well, this selectivity reduces confusion, simplifies decisions and makes attention easier, more focused and more powerful.

Consider now the two limits of internal complexity. If every component (worker, team, or group) were to act independently without coordination, a large number of independent states would be generated. But this would not be useful to the organization because there would be no alignment, synergy or direction; in other words, no coherence only isolated independent behavior. At the other extreme, if every component were constrained to behave in a predetermined way so that the organization became a rigid structure whose relationships were tightly controlled, the organization would become a classic bureaucracy and would be unable to deal with today's rapidly changing markets. It would be unable to adapt and respond fast enough to keep up with either its competitor's actions or its customer's needs. Neither the strong independent nor the tightly controlled forms of internal complexity will work. Somewhere in the middle region lies the organizational state of *optimum complexity*, the right level of complexity to deal with the external environment while maintaining sufficient order and unity of purpose.

Selectivity, as the filtering of incoming information from the outside world, will always occur. Individual attention is usually limited to one thing at a time (groups often have difficulty staying on a single topic). Because of the sheer volume and lack of control of outside information impinging on the system, natural selectivity at the boundaries of the organization may become erratic and create more random than purposeful action. This is exactly what system components (such as teams or self-organizing groups) are supposed to prevent. By analyzing incoming information through

internal communication and “group digestion” of unusual events, the organization improves its filtering ability. Good filtering requires broad knowledge of the environment, specific knowledge of the customer and a strong sense of the organization’s strategic intent. Many opportunities can be lost if the organization cannot recognize and interpret the meaning and consequences of seemingly benign signals.

Knowledge Centricity is the aggregation of relevant information derived from the knowledge of the organization’s components that enables self-synchronization and increases collaborative opportunities while promoting strategic alignment. Knowledge Centricity closely supports Organizational Intelligence since to behave intelligently a complex adaptive system must achieve continuous, interdependent collaboration and interplay. Since information flows are dynamic in nature, powerful aids (such as search algorithms, intelligent agents and semantic interpreters) are needed to allow people to rapidly retrieve information to formulate viable problem solutions but also give them the confidence that the information is current, accurate, and complete enough to make sound decisions. Knowledge, the actual and potential ability to take effective action, is at the heart of the ICAS.

Flow enables knowledge centricity and facilitates the connections and continuity that maintain unity and give coherence to organizational intelligence. The ICAS organization flourishes from the flow of data, information and knowledge; the flow of people across and in and out of the organization; and flow in terms of the optimal human experience. The flow of data and information is both horizontal and vertical, including the continuous, rapid two-way communication between key components of the organization and top-level decision-makers that is essential to unity and shared purpose.

Permeable Boundaries is an essential characteristic of the ICAS that differentiates it from a classic bureaucracy. The virtual world of the ICAS breaks down the historic understanding of relationships and boundaries in terms of time and space. Over time as people come in and out of the organization driven by increasing and decreasing demands, the “boundaries” of the organizations become more difficult to define. As ideas are exchanged and built upon, the lineage of these ideas becomes impossible to follow. Add all of this to a fluctuating, complex environment that is constantly changing and one can understand just how important permeability and porosity are to survival of the next generation knowledge organization.

Multi-dimensionality represents a number of competencies that ensure ICAS knowledge workers have the ability to view the environment from many different perspectives and to apply a variety of thinking styles and core competencies to issues and problems. These capabilities give the organization an ability to continuously forget and learn; to identify and deal with risk; to think in terms of systems; to rapidly shift its frequency of operations; to perceive and analyze situations in terms of wide scope of possibilities and long time-frames, all the while maintaining its organizational identity and unity. While too much incoming information can produce overload without effective filtering, too little information prevents understanding of the external world and its potential threats and opportunities to the organization.

The connection between *processes* and relationships within the organization and its emergent properties is complex and difficult, if not impossible, to follow via cause and effect chains. It is also difficult at best, and typically impossible, to predict the precise nature of emergent characteristics. This is one reason why planned change is so difficult and the change process so hard to control. For instance, it is easy to create a vision of a team-based organization with high employee empowerment. But, the exact details of the best team structure or the specific way that employees should be empowered are very hard to predetermine.

People are not machines and their variability and self-determination are essential for their efficacy. Thus, while a desirable emergent characteristic can be nudged and guided, it cannot be decreed. Every one of the eight characteristics of what we call ICAS must emerge in one form or another from the nature of the organization, and cannot be pre-designed and implemented by managerial fiat. These top-level properties best describe the necessary conditions for the optimum operation of four major processes that deal effectively with the external environment and with stakeholders. These processes represent the primary ways that organizations prepare for and take actions that affect their environment and thereby ensure survival. The processes are: Creativity, Problem Solving, Decision Making and Implementation.

The Four Major Processes

Creativity is the human act of generating new ideas, perspectives, understanding, concepts or methods that help in solving problems or building new products. The organization has significant influence on the development and effectiveness of *creativity* through its strong influence over the operating environment within which employees interact. A creative environment requires open communication, collaboration, a playful attitude and critical thinking, coupled with a clear vision and objective. Such an environment encourages new ideas and different ways of seeing things, resulting in employee out-of-the-box suggestions for solving problems.

Problem solving is one of the most important processes in the organization. Problems can be solved by individuals, teams, networks, or communities of people. Taking inputs from the creative process as needed, the problem solving process provides the link between problems and decisions. The output of the problem solving team is a set of alternatives that provide ways to achieve a desired situation or problem solution.

Decision-making refers to the selection of one or more alternatives generated by the problem solving process. There is no single way to make decisions: it is both an art and a science. Decision-making cannot be avoided where responsibility is concerned. In a complex adaptive system all workers may be purposeful goal-seeking decision-makers. In the ideal ICAS decisions are made at all levels, with each level having a domain of decision authority commensurate with their experience and scope of responsibilities. Although Team decision-making is more complex and time consuming than individual

decision-making, most of the difficult and complex decisions are likely to be made by teams because of the potential improvement in decision quality.

Finally, results make the difference. Making high quality decisions is essential to getting good results, but it is not enough. Taking good decisions and turning them into actions and changes that create improved products is a major challenge for all organizations. When individuals who have responsibility for *implementation* are aligned with the decision, implementation becomes much more effective. Big decisions that set the fundamental tone and nature of the ICAS require greater understanding and support throughout the organization. Ultimately, implementation is built on relationships and knowledge. Efficiency and clarity of communication, coupled with openness and a sincere concern to share understanding and get participation is a tenet of the ICAS.

In this short overview paper we have suggested certain organizational characteristics that will contribute to long-term success in the future storms and opportunities that lie ahead. We have additional papers that explore these characteristics in greater depth, investigate the relationships among these emergent characteristics, and discuss the interdependency among these characteristics and the four major organizational processes.

Notes:

¹There are a number of biological systems that possess capabilities needed by organizations to survive and compete. Neo-Darwinism survival has produced organisms with modes of behavior that most organizations would consider unattainable. Nonetheless, we find it useful to use living systems as a source of metaphor and insight in developing our organization for the future.

² One of our main resources is the work done by the Nobel Laureate Gerald Edelman and associates who seek to understand consciousness through research in neuroscience. We also have made use of Karl Wiig's studies on knowledge management and intelligent behavior. Csikszentmihalyi's extensive work on flow theory provides insight from psychology into the desirable internal movement of relationships and data, information, and knowledge management. Ralph Stacy provides many ideas from his studies on complex adaptive systems and organizations.

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