NetAge Working Papers

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A Measure of Complexity

Organizations as Complex Adaptive Networks

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> *NetAge Working Papers* set out a new theory and practice for organizations. We feel compelled to publish these papers now as an urgent response to the collapse of traditional hierarchies and bureaucracies as evidenced by the current economic debacle. As the economic crisis deepens in 2009, we believe that now is the time for new ideas, new concepts, and new theory to come forward, approaches that will allow all kinds of organizations whether large or small to reorganize in smarter, better, and faster ways.

In this paper, we apply complexity concepts to organizations and define a "complex adaptive network" tuned for organizational use. This context underlines the importance of combining the vertical reporting 'reproductive' links with the complementary but less-recognized horizontal process links of a 'work relationship'.

This is also speculative paper. We set out a step-by-step recipe for calculating and using "K"—the putative measure of complexity and interdependence—in any organization, large or small. We then look to those players one link (neighborhood), two links (community), and more (environment) away and speculate about K values for external boundaries. We end with "intelligent collaboration."

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Avalanches of Change

We live in an age of avalanches, very near the edge of chaos, just beyond the confines of order. Great processes—like evolution, creativity, innovation, and just plain survival—operate everyday in the zone that spans order and chaos.

As the great revolutions of our time cascade us with vast variety, our collective social environment has become of supercritical importance. In such times, the "butterfly effect" of chaos, where small cause works great change, rises as hurricanes from gentle breezes, born in turn from faint rustling a world away.

How do such moments feel? They're remarkably like the day we first drafted this page, October 28, 2004. That moment, for us, was the day after our hometown baseball team, the Boston Red Sox, won the 100th World Series. For the first time in 86 years, they broke a legendary sports curse, imposed when the Boston team sold its star player, Babe Ruth, to their arch-rivals, the New York Yankees. An entire planet of sports fans was aware, for a moment in 2004, of how a self-described "group of idiots" played at the edge of chaos and prevailed 4-0 in a best-of-seven championship series. This win, unusual but not too strange, had followed an improbable feat unique in the previous 99 years of play. They came from behind (down 3-0) to four straight wins in league championship against their ancient foe, the Yankees. That the Red Sox then broke "The Curse of the Bambino" during a lunar eclipse right in the middle of the last game of the World Series, the blood-red moon hanging over St. Louis and visible in Boston under clear skies…well, the odds of this? They are very slim.

Of greater moment that day for all those who didn't live in Red Sox Nation was the looming U.S. presidential election the following week. Four years earlier, the world saw the butterfly swoop into American democracy as a hanging chad and land in the Supreme Court, bringing George W. Bush to power. Four years later, the U.S. political situation was super-critical again, only more so. (Never mind that it was a Red Sox fan, John F. Kerry, carrying the banner of opposition into the 2004 presidential election.) All agreed that the volatility of the moment promised another collision between fluke and fate.

Why were we all holding our breath? For Red Sox fans, the last out in the last inning of the last game was a gigantic exhale, relief from breath-taking anxiety based on long experience that one tiny event—a missed ball or swing of the bat—could change the course of history. For political fans, and citizens of the world, our collective breath was taken away by our shared sense of the instability of the moment. We all feared the butterfly's flap. What little events would tip elections and unleash avalanches of unforeseen consequences?

We did not need the outcome of the election to know that both American and global civilizations will grow only more volatile in the years ahead. Both U.S. presidential campaigns in 2004 presented visions of apocalyptic change, albeit with different protagonists. It was not so different in the election of 2008. The volatility because only too evident as that campaign rose to its climax, and the global economic crisis rose to a roar.

For some, we are in an ongoing struggle between good and evil, centuries, even millennia old; for others, the conflict is between tradition and progress, fundamentalism and the future. In either view, a great struggle is underway and ongoing, elections and wars only events along the way.

New technology and globalization have made this larger moment of complexity inevitable. Forces of order and chaos must clash, feeding pressure for resolution into one of the two competing states. Over the long view, change has won out, riding the back of evolution toward greater complexity. Along the way, however, the evolutionary course zigzags its way to progress, catastrophes followed by leaps ahead, chased by small falls, and then by avalanches of change.

Today, in this era of so much potential for catastrophe – environmental, nuclear, terror, and economic—we as a global civilization (perhaps even as a species) are zooming high without a net. As the human crowd, we have an unease born of our knowledge of how a small error can lead to now unimaginable catastrophe. Our gut wrenches as we fear to look at just how far back we might be set. But, then, a small success here, a little invention there, can propel us—we don't know how far—forward.

We are looking to get an organized grip on ourselves.

> *How do we greatly expand our ability to work together? We can radically improve our organizations. Not by changing people, but changing how we organize ourselves. Let people be people—in better, smarter systems of collaboration.*

Big Picture Capstone

We are more than we imagine, together much more intelligent than any of us alone. *We,* acting together in small groups and large as integral entities, as an *us*, are the next really big step in evolution beyond the human organism, beyond us as individuals.

We are naturally networks. Organizations are part of the natural order of things, one kind of system of parts and relationships. Networks of organisms have evolved on top of the evolution of sentient species.

Every big picture view of systems on this planet sets out the same huge steps. This whole-part staircase of increasing complexity includes:

- *Atoms* (themselves complex) that combine into
- *Molecules* that comprise
- *Cells*, which, 500 million years ago, organized as
- *Organisms*, now tipped with you and me, that combined into

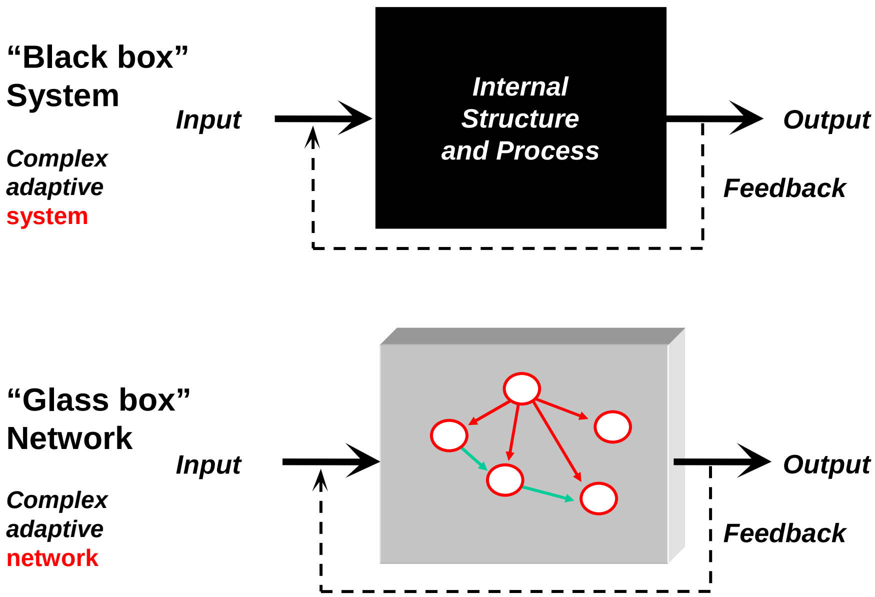
- *Organizations*, clearly already the next step in the planet's evolution.

That our organizations are our successors in the march of evolution seems obvious from the pattern, yet it can be so difficult to see. Since *we* comprise an organized *us*, we are as fish in the sea. We need a way to see our surrounding medium—an ephemeral configuration of ephemeral organizations of ephemeral nodes and links.

Complex Adaptive Networks

Complexity scientists casually use the term "agents" to reference both a single system and a group of systems. When agents (systems) interact to produce a new level of organization (assemblies of systems), emergence takes a very big step. This is where we focus here, the system that arises from self-organizing agents, the "complex adaptive *network*."

Figure 1: Black Box Systems vs. Glass Box Networks



Since complexity scientists invariably treat multifaceted *systems* as *networks*, this may seem a small point of terminology. However, after a quarter-century of studying human networks in place of human systems, perceiving organizations through network glass boxes rather than black box systems (see Figure 1), we think it is important to call a network a network. To define it then:

> *An organization is a complex adaptive network of people in a configuration of positions. People who populate an organization are themselves complex adaptive systems.*

Applied to organizations, the network concept helps us see both configurations of relationships and collections of constituents. So, are organizations complex?

In the sequence of terrestrial steps in the Big Staircase of Evolution (*atoms, molecules, cells, organisms, organizations),* cells and multi-cellular organisms are on everybody's list of complex adaptive systems. There is some question about where to cut off the low end of the complexity scale. Specifically, can molecules meet the tests of complexity? Murray Gell-Mann, the Nobel-winning particle physicist, regarded as the *eminence grise* of complexity theory, thinks not. His colleague, Stuart Kauffman, on the other hand, thinks so, having tuned his brand of complexity theory to read molecular networks. Some complexity thinkers, like Harold Morowitz, trace complexity principles and patterns back through the evolution of atoms and particles to the formation of the Universe itself. [1]

But at the high end of complexity on earth, Kauffman, Gell-Mann, Morowitz, legions of systems theorists, and nearly everyone else who's thought about it agree: When conscious, symbol-wielding beings gather into organizations, we undoubtedly have a complex adaptive system on our hands. Or, we would say, a complex adaptive *network*.

Naturally, systems of compound structures are more complex than their parts. Thus, integrated assemblies of us must be more complex than we are as individuals. Our approach is to root this extra measure of complexity in the objective design of the configuration, in the chart of the positions rather than in the subjective people who flow through it.

Organizations are multi-organisms like organisms are multi-cells. The where and how of every cell in the body is connected to every other cell through a configuration that has evolved over the more than three-billion-year span of life on earth. Moreover, each cell just happens to have a copy of the whole organism plan tucked away in its own internal machinery.

The ability of cells and organisms to model the world is one hallmark of complex adaptive systems. In Gell-Mann's view:

> *A complex adaptive system acquires information about its environment and its own interaction with that environment, identifying regularities in that information, condensing those regularities into a kind of 'schema' or model, and acting in the real world on the basis of that schema.*[2]

The taxonomy of interrelated jobs is a schema, a pattern of regularities. Such a model provides a view of the organization's internal world and how it interacts with the world beyond its borders. This schema functions as an organization genotype, a condensed code that unfolds as a map of the whole organism.

We saw the level-by-level growth of our Eleum case study's configuration as it unwound from its origin, the CEO, over a nine-month formation (see "Revolution in Networks"). Eleum's design, its initial schema, came to life with the hiring of people into newly minted jobs, starting with the anchor position. We've gathered, visualized, and analyzed current data about the configuration, revealing the unfolding of the plan and the modifications made since its inception (see "The Virtual, Networked Organization").

The schema of this 100-year-old company is heavy with history. It bears traces of countless ancestor jobs, ways of making a living that have been honed over time, some for millennia and centuries, others for decades and years. The organization is still shaping itself, racing along, bumping into the world, learning and adapting as it goes. Inside, the configuration of positions struggles to keep up, morphing as needed—or crashing when it can't.

General Holon Principle

Arthur Koestler, the great Hungarian novelist and systems theorist, originally coined the word "holon."[3] With it, he concisely captures the idea that everything—atoms, cells, solar systems, cars, people, everything—is simultaneously a *whole* in and of itself and a *part* of something larger: Systems-within-systems-within-systems. Called "hierarchy" by scientists, the holon principle captures the widely-recognized idea that life, the universe, and everything in between structures itself in levels—sub-systems comprising systems within supra-systems.[4]

Why is the holon principle so universal and so powerful?

Nobel Laureate Herbert Simon calls hierarchy the "architecture of complexity." In arguably the most famous and oft-cited paper in systems science, [5] Simon says that complexity evolves from simplicity through subsystems which have "stable intermediate structures," subsystems sturdy enough not to pull apart. Hierarchies predominate in nature, he says, because "hierarchies are the ones that have the time to evolve."[6]

Simon's insight is reflected in the structure of systems across every domain, from physical to biological to social systems—and even that of systems theories themselves. Hierarchy is the most-universally recognized, fundamental, systems principle. Natural systems like organizations cope with increasing complexity by evolving a hierarchy of levels, following a profound, natural design principle.

Organizational experience also leads to this multi-level conclusion. Scientific models of organizations must account for the near-universal presence of hierarchy observed in real-world instances of even the most networked organizations.

> *As a matter of evolution, principle, and experience, it is highly likely that real organization networks reflect hierarchy.*

This hierarchy requirement presents a challenge. Both Albert-Laszlo Barabási and Duncan Watts have written that understanding how hierarchy shows up in networks is at the cutting edge of the new science. We have shown that, at least in organizations, hierarchy may be considered a special case of a network. Organization networks are inherently hierarchical in the scientific sense of level structure.

Hierarchies, multi-level structures, emerge from successive processes of emergence.

Emergence in Networks

The first standard network model was developed in the 1960s by mathematicians Paul Erdõs and Alfred Rényi. They assumed that nodes—e.g., people, cells, molecules, and atoms—and their interactions are so complex that it is best to render them simply. To do so, they chose uncomplicated structures—either random systems or highly-structured lattices. To study networks as nothing more than a mesh of points and lines, they developed and applied "graph theory."

Perhaps their most notable finding comes from their proof of *emergence*, the remarkable property of self-organization. In both simulations and physical experiments, networks perform the same magic trick. When links are added one-by-one to populations of nodes, something remarkable happens when the average number of links per node approaches one. Suddenly, a whole "giant cluster" *emerges* out of the fragments of random connection. In a flash, most of the previously-isolated nodes spontaneously link up into a single network. This step-change transformation, where each node has one link, has been confirmed in research across many scientific domains. The whole becomes something more than all the disconnected parts; synergy happens. Emergence is at the core of today's cutting-edge studies of chaos and complexity, elaborated with mathematical elegance.

One node, one link? Sound familiar? Are the hierarchies we live in the logical equivalent of an emergent giant cluster? In our study of Eleum's hierarchy, are we in fact detailing its giant cluster infrastructure?

A hierarchy may be a standing wave of emergence.

There is something creative in the heart of human hierarchy. It is a dynamic structure continuously reforming as it self-organizes, cycling rhythmically through increasing chaos to moments of spontaneous coherence.

The Emergence of K

Today, the light of emergence shines most brightly in complexity science. Complexity thinking is the artful juncture of systems concepts, new network mathematics, updated catastrophe-chaos-avalanche theories, and its own strong focus on self-organization and emergence.

Particularly brilliant is the fundamental premise of this school of thought: that evolution—the branching that matters to us—expands relentlessly toward greater complexity. Evolution does not trend toward more order as most systems theorists have assumed. Indeed, the new view is that emergence and self-organization live somewhere *between order and chaos* in a dynamic zone of complexity.

Luckily for us, the general theory comes neatly packaged in chunks of "complex adaptive systems." Complexity scientists inevitably model these chunks as networks, which fit very nicely with our conceptual framework for organizations. Complexity offers us more concepts and tools to supplement the new network science we already are applying. Especially attractive is the promise of ways to look closely at that rich but elusive gap between order and chaos.

Enter Stuart Kauffman. Kauffman blew our socks off with "K." In his book, *At Home in the Universe*, he writes:

> *Whence cometh the order? The order arises, sudden and stunning, in K=2 networks…. I hope this blows your socks off. Mine have never recovered since I discovered this almost three decades ago. Here is, forgive me, stunning order… Order for free.* [7]

Calculating K is extraordinarily simple, the ratio of links to nodes.

K = links / nodes

Nodes and links are, after all, the warp and woof of the human networks we have been exploring for a quarter century. Kauffman, a Santa Fe Institute founder, MacArthur Fellow, and evolutionary biologist, had gotten our attention.

K from Zero to Two

The journey from a state where K equals zero, where nothing is connected, to a state where K equals two, makes for a fascinating story with predictable challenges: Like every great journey, there are two major trials along the path, two points of emergence. The first transition appears as K approaches one; the second marks "the edge of chaos" when K nears two.

When K is equal to zero, the world is network-free. There are nodes but no connections among them. What happens if you just start to add links, the classic experiment in first-generation network science? Collect a population of nodes together, then connect them randomly, one link at a time. For most of the ride, nodes remain fragmented, standing alone or joining up in pairs, with an occasional small clump forming. As the average number of links per node climbs toward one, things thread together more. Just as K approaches one, a giant cluster emerges where most of the nodes now connect, forming a single system.

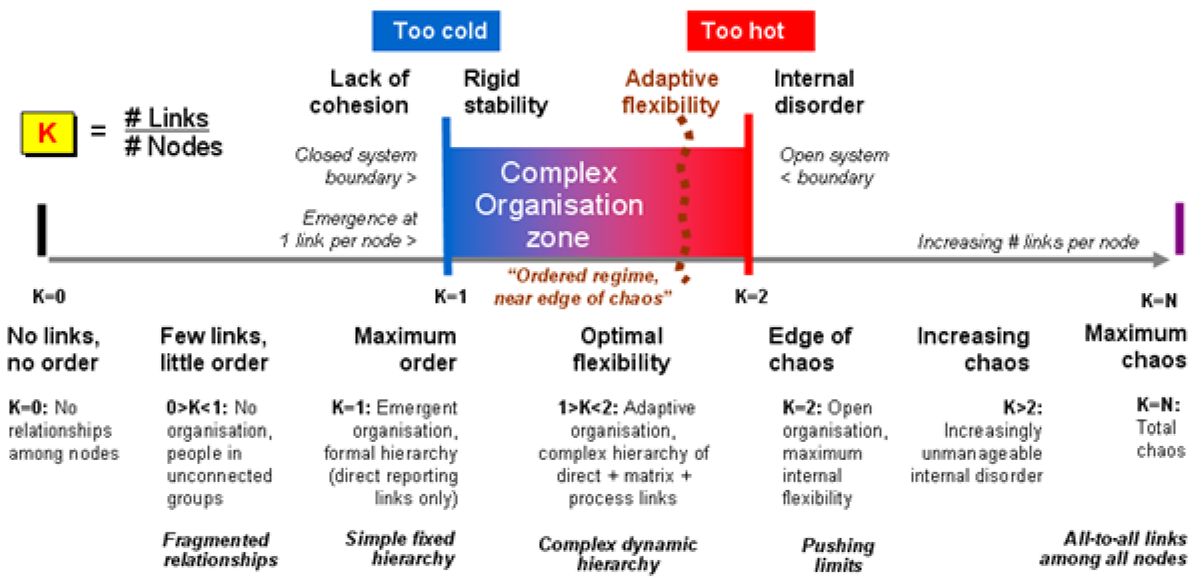
Here a new level of organization arises out of the previously isolated parts. This is the first boundary condition of one link per node. A phase transition occurs. An interconnected whole emerges from a critical mass of relationships among parts. In complexity terms, greatest order prevails when K is equal to one, tendering maximum rigidity with minimum flexibility.

We recognized this pattern. It was Eleum's hierarchy. Quite simply, the pattern of one solid-line reporting link per node produces a network state where K equals one. So, we thought, what happens when K goes beyond one and approaches two? What about beyond two?

Kauffman gets to a network where K equals two starting from a state of chaos, where everything is connected to everything else. Chaos maxes out when all nodes are connected to all other nodes (K = N-1). From here, Kauffman begins to patiently cut connections among the nodes. Remarkably, he has to remove the vast preponderance of links before closing in on the second point of emergence, where K is equal to two.

What Kauffman calls "stunning order" shows up when K equals two. The network of relationships itself provides what he terms "order for free." He had found the point where the laws of complexity apparently decree that self-organization begins. After many years of work, much of it with genetic regulatory networks, Kauffman observes that complex systems seem to need to stay inside the boundary of order, yet get as "near the edge of chaos" as possible, or necessary, to survive (see Figure 2).

Figure 2: Optimal Configuration Near Edge of Chaos



What does chaos mean for organizations? To call it chaos when every node is connected to every other node, like a close friendship network, is startling. Small groups may work with all-to-all connections, but what happens when you're talking about large groups of 500, enterprises and institutions of 10,000 or 100,000 people, or even rare organizations of millions like the U.S. or Chinese governments? The combinatorial options quickly become hyper-astronomical as the population of nodes increases. To be precise, the number of possible relationships among any number (N) of nodes is calculated as two raised to the N^{th} power. Once the number of interacting nodes goes beyond a few digits or so, the range of all possible occurrences becomes like the number of atoms in our body with 27 trailing zeroes, soon outstripping the number of atoms in the Universe.

It would appear that the organizational imperative is to maximize flexibility without losing complete control. You can fail with too few links, and you can fail with too many. In short, for a surviving, thriving system, look for a K value between one and two (1 > K < 2).

This gives us two theoretical boundaries, one that defines the population of nodes internal to the system, the *closed-system* boundary where K is equal to one, and a second *open-system* boundary with the external world where K approaches two. Remarkable, if true.

> *K purports to be a gauge of self-organization, a measure of that thin line in complexity between order and chaos.*

From Systems to Agents

Structure and process are grand concepts. Fortunately, they neatly compress into nodes connected by vertical and horizontal arrows, just what we need to construct a network (see "Organizational Networks: Core Concepts of People, Positions, and Relationships"). Stuart Kauffman's extremely economical definition of a complex agent can be expressed these two types of relationships:

> *An autonomous agent is a self-reproducing system able to perform at least one thermodynamic work cycle.*[8]

The mouthful, "complex adaptive system," can be reduced to the term "agent." To qualify as an agent, a system merely needs: (1) evidence of its ability to reproduce; and (2) a way to work.

For organizations, the first requirement is already met by a hierarchy that unfolds from whole to part, from top to bottom, from root to leaf. Indeed, in coding hierarchy in software, we talk about "parent" nodes having "child" nodes at the next level down. The whole *is* the sum of the parts with respect to the primary direct reporting relationship. But that is not enough for agency.

To meet the second requirement, an organization must have at least two internal components in an input-to-output relationship. Work relationships between functions separate an organization that is a complex adaptive system from a collection of jobs. Practically, the internal direction of the process flow must line up with the organization's role in its external work process, its niche. Doing work is what organizations are about.

Positions, then, play in both the hierarchical taxonomy of jobs, and the internal process model of work. Relationships—both those based in reporting and those resulting from process—sculpt a position within a design of other positions that adapt to the same strong internal forces. In network terms, these forces are modeled as "directed" links, connections with a will, arrows pointing from here to there. Each carries a strong compulsion, acting as a "force" to use a physical analogy. There is nothing wishy-washy about these relationships.

Hardly a secret from the rest of us, the force exercised by superior over subordinate is the most well-known relationship in management. While the command from whole to part is not absolute—and may be shared in matrix relations—it is a very strong natural force in organizations.

Internal process flows carry the authority of their place in larger processes, especially the process that defines the niche for the organization as a whole. This flow carries the compulsion of time, from before to after. Although the output imperative generated by this force can be challenged by authority, even reversed by design as in a feedback loop, the upstream-downstream flow is nevertheless the main route to organizational survival.

Process connections are, we believe, the essential links missing from typical pictures of an organization's structure. These flows give life to the configuration of positions and, potentially, the measure of K.

Finding K in Organizations

It sounds abstract, but juggling *order* and *chaos* is really a very visceral experience for many leaders. Their jobs are to manage the daily tension between too much and too little of each. Managers, particularly senior ones with design responsibility for how the organization is put together, are ever-seeking to optimize stability and flexibility in a competitive, chaotic environment. The stakes are huge for getting K, the ratio of links to nodes, right.

Maybe K will turn out to be the "measure of complexity" Patrick Robertson, one of our senior sponsors at Eleum, has pushed us to find since early in our pilot project. He wanted an objective way to characterize the organizational complexity of a unit for comparison with existing performance metrics. At the intersection of complexity and performance measures, he hopes to find organizational leverage and best practices for design. He wants a way to work smarter, better, together.

We already know a lot about the configuration embedded in Eleum's human resource data where K is equal to one. Within that 5000-position organization, each of 650 management positions serves as the root of a sub-network of some size and depth. Thus, we can calculate such network metrics as level, size, and span for all of them. Given the simplicity with which K can be generated, it is equally possible to determine at least one such complexity indicator for each leadership position—or two, if the sub-organization is more than two levels deep.

So here we are, with our map of Eleum where K is equal to one. We have taken a few steps into territory where K is greater than one, based on our pilot collection of matrix reporting links within the hierarchy. Could K possibly be real for organizations? Our internal skeptical selves say it's most likely a metaphorical mirage, but, if true, would be of considerable value.

Calculating K

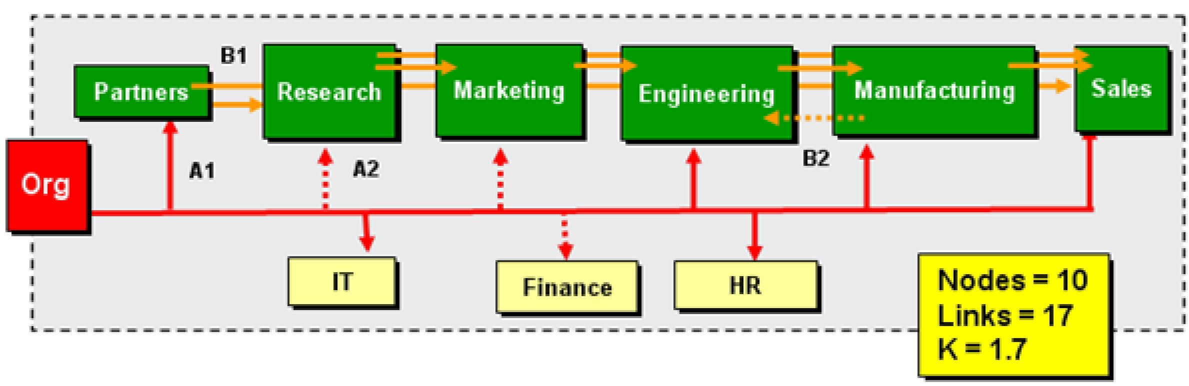
How do we calculate K to test it? Actually, the calculation itself is amazingly simple, plain division, no advanced math or supercomputer required. What's hard is defining which nodes and links to actually count for calculation. What to include, what to leave out? In truth, though, defining the nodes, as positions occupied by people, also is relatively easy—just count the jobs. Determining which links to count is much harder to do. The trick is to draw the pattern with as few lines as possible while capturing the essence of the whole.

To calculate the complexity measure of an organization's internal design, we propose this: Combine into one network picture both reporting connections and work-process links. Use "from-to" logic to determine a common direction for the links, both vertical and horizontal (see "Organizational Networks" cited above):

- *From* whole *to* part for reporting relationships, and
- *From* input *to* output for process relationships.

To illustrate, let's look at an example of how decision and process flows connect a small group of positions in a typical commercial organization. Figure 3 is not unlike Eleum's configuration. Here we make an atypical diagram by combining two typical types of pictures into one.

Figure 3: "K" in Complex Organization Example



The first type of picture, the organization chart, what our European colleagues call the "organigram," reflects the most fundamental discovery of 50 years of systems thinking. This is the ubiquitous principle of hierarchy, the structure of nested wholes and parts, Simon's "architecture of complexity." Hierarchy, in the scientific sense, is as close to a universal as we have in any 'Theory of Everything'.

The second type of picture shows process flow in its most mainstream formulation. Usually a system is rendered as a "black box" with inputs coming in on the left and outputs going out the right, sometimes with a feedback loop going upstream from output to input (see Figure 1). While the hierarchy structure is a sparse, elegant principle of almost metaphysical attraction, the input-output process model of systems is a plain-spoken, nuts-and-bolts sort of conceptual tool.

Nowhere has the input-output systems model been more widely adopted than in the organizational and management sciences. It has shown itself to be very practical over the whole range of human scales, from managing small projects to positioning firms along supplier-to-customer value chains. Upstream-to-downstream economic flow courses through broad markets and deep into the crevasses of the smallest sub-organizations.

Let's look again at positions in these two contexts. Positions chunk an organization's internal world, differentiating it into a finite set of interrelated categories. A reporting link puts each category in the configuration into a superior-subordinate relationship with another category in the set. We have seen how these simple links can generate large multi-level networks of ordered relationships, as in the Eleum example.

However, just chunking the world is not enough. We need to chunk it into the right functions, and link it together into a smart enough configuration that the system is able to make a living, to survive and prosper. This is what you look for when you open up the "black box" management system, the key nodes and the configuration of process links that drives the system as a whole.

Process relationships among positions are implicit in the category labels themselves, which are literally the sub-organization names and position titles. Drawing the process relationships simply reveals the linkage inherent in the interrelated terminology. For example, units labeled R&D, engineering, manufacturing, and sales carry with them an implied upstream-to-downstream process order.

While solid-line reporting relationships remain the gold standard for formal, objective organizational links, process connections are as about established and explicitly recognized as matrix reports. Process links, like matrix connections, are well known locally, but incompletely understood globally. Knowledgeable people know how the local organizational pieces inter-depend, how the work flows and how it's being supported. That information, however, is rarely collected into an explicit model of the whole organization.

In mapping Eleum's matrix links, we noticed that they largely described how services provided by organization-wide resource functions are distributed to other functions. Matrix connections based on providing services generally showed up a level or two down from the top-level function. Missing from the reporting map are the connections between the workflow functions. Workflow functions that deliver the organization's output generally follow an industry-wide template. This upstream to downstream flow of internal specialties produces an external output.

The Eleum leadership team diagram had a highly-flexible K value of 1.7, near the edge of chaos. When we showed the picture to the Eleum CEO, he grumbled, "Maybe it's not exact, but it's pretty close."

Strong Links Defined

We lay out a taxonomy of link types in "Organizational Networks," including "A-type" reporting links and "B-type" process links – so-called "strong" links. Organizational hierarchies are interdependently connected by direct reporting and, perhaps, matrix reporting links. If every complex agent has at least one work cycle, then at least one process relationship must be in the mix. Feedback links also are optional, but may appear anyway. These, then, are the formal relationships essential to the internal organization, along with their rules of use:

- Reporting Links (A)
  - ***A1***: **Direct Reporting**, where every position has one and only one direct reporting relationship; the set of nodes in a path of direct links to a root defines the organization core membership.
  - ***A2***: **Matrix Reporting**, where a position may have multiple secondary matrix reporting relationships; it cannot have both a direct and a matrix reporting relationship to same node.
- Process Links (B)
  - ***B1***: **Primary Process**, where every agent has at least one input-output work relationship between two component nodes.
  - ***B2***: **Feedback Process**, which provides both dampening and accumulating loops; two nodes may have both primary process flow and feedback relationships between them.

We establish a toehold in organization complexity by mapping the hierarchy using one of the strong forces, direct reports (A1). From the hierarchy base, a more comprehensive model of internal complexity emerges from the more subtle pattern of all four strong forces of organizational configuration.

Fundamental forces of structure and process are, we believe, the dominant ones for defining the internal configuration of positions. Here, then, is how we propose to calculate K for an organization.

> *Take N positions that connect to a root node by N direct reporting relationships. Add additional matrix and process links between those positions, as necessary. Sum all the links and divide by N.*

Seems simple—most likely, too simple. But, there is a significant payoff for large-scale human problem-solving at this critical point in history if K proves applicable to organizations.

Search for K Enriches Hubs

In seeking K, we have unconventionally added process links to the usual organigram of reporting links. This potent mixture adds richness to the analysis of hierarchy, bringing the organizational configuration to life. We can calculate these strong links, separately and in combination, for every job in the organization. These measures are particularly illuminating for management positions, the interacting pattern within the whole.

For positions connected by both structure and process links, both “in-degrees” and “out-degrees” are meaningful. These measures refer to the count of arrowheads pointing in the same direction, either into or out of a node, whether vertically or horizontally aligned. Moreover, these degrees can be calculated for each type of organizational force and its impact on one position.

With hierarchy, we see only one type of hub, the downward-facing reporting spans of management. When we add matrix links, reporting spans continue as the focus of hub and hotspot drama. The relative handful of positions accountable to two bosses hardly registers, not even the rarer few with more than two matrix reports. This is true despite everyone knowing how tough it is to have more than one boss, considerably more difficult than having a few more people reporting to you.

The situation becomes much more interesting when we join in process links. A position may have multiple process inputs from other functions as well as the decision inputs from a primary direct-link boss and perhaps one or more dotted-line bosses. Now *input* hubs, places of process and reporting confluence, show up alongside *output* hubs, themselves newly enriched by process linkages.

A huge amount more information about the organization network schema is available by adding matrix and process relationships to a core hierarchy network.

Benefits of Knowing K

By mapping decision and process flows together, we gain a better picture of the formal organization’s complexity than by analyzing the hierarchy alone, with process hubs revealing themselves alongside the reporting hubs. K is just a potential (big) bonus to the basic program of scale-free and small-world modeling suggested by the new network science.

If K arises in organizations, we see a number of ways to use it as a rule-of-thumb measure:

- As a diagnostic (Is the organization too inflexible? Too out of control?)

- As a target (Do we need to increase our creative capability here? Do we need to reduce complexity to improve safety there?)

- As a tuning device (How can we best adjust and adapt to external forces?)

As a network metric, K appears to be completely scalable, applicable to organizations small and large. For leaders of multi-level organizations, there is a complexity measure for the leadership team as well as the whole network sub-assembly of positions.

Here, maybe, is the complexity measure sought by our Eleum sponsor. Comparisons with performance measures may suggest optimal ranges for different types of organizations and sub-organizations. People, with their own preferences for more or less stability or flexibility in their jobs can be better matched to jobs that suit them.

> *The web of relations changes, adapts, and evolves dynamically in and around the human players—holding the whole together.*

Neighborhood, Community, Environment

Recognizing the already speculative nature of the application of K to internal organizational network dynamics, it is nevertheless inviting to go out on even shakier ground to account for the open-systems reality of real-world organizations.

Can we extend the idea of K, the measure of cross-coupling, to an organization's one-degree neighborhood, its two-degree community, or to more distant contexts? The investigation of higher K realms is required as we extend the organization network map to include other node groups and relationships.

"Who are we and what do we do?" We have hitherto placed a sharp boundary around the "we," defining internal positions as those connected to a root by a hierarchy of directed reporting links. This mirrors well the old-paradigm view of a closed-boundary (K = 1) hierarchy-bureaucracy, but it misses the true nature of the inter-penetration of internal and external boundaries of open systems. While we have opened up the internal configuration with process links and explored the elusive boundary between order and chaos, we have held tight to the core root set of hierarchy-identified nodes.

Knowing who *we* are, who is inside and who is outside, is crucial. But we are not alone, and all outsiders are not the same. So, carefully, ever so carefully, we open up the model to external actors that play crucial roles in the organizational drama.

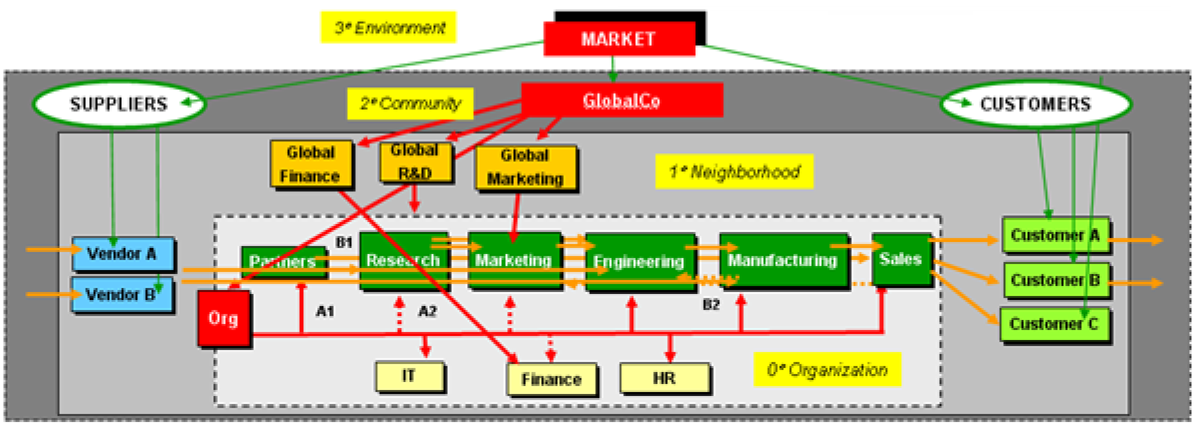
1. Neighborhood: One Link Out

We look, first, one link out from the perspective of each node in Eleum's network. Each node asks who are its neighbors, nodes one link away?

Eleum's internal "inside neighborhood" has already been accounted for in the core configuration. Some positions, however, are connected to external actors, players essential to the organization's ability to function in its environment—and survive (see Figure 4). An organization's:

- Matrix reports may stretch to external managers;
- Output functions may connect with external customers;
- Input functions may link to external vendors;
- Contractors and consultants are one link away; as are, perhaps,
- Regulators and other key stakeholders.

Figure 4: Neighborhood, Community, and Environment



It's a big and important world that is connected within one link (one degree) of any node in the core (root) network. Network science knows this as the "network neighborhood." From the perspective of a root point of reference, an organization's neighborhood is defined as the network of nodes connected to core member nodes by one directed link, in or out.

An organization network's neighborhood of direct working relationships includes its most vital connections in the adaptive play to live long and prosper. This close-in set of external relationships is becoming ever more important as the current corporate focus on core competencies combines with a still-accelerating trend to outsourcing. These opposing forces are tearing apart the old-style top-down hierarchy that does everything. Internal and external functions are re-integrated through complex network relationships.

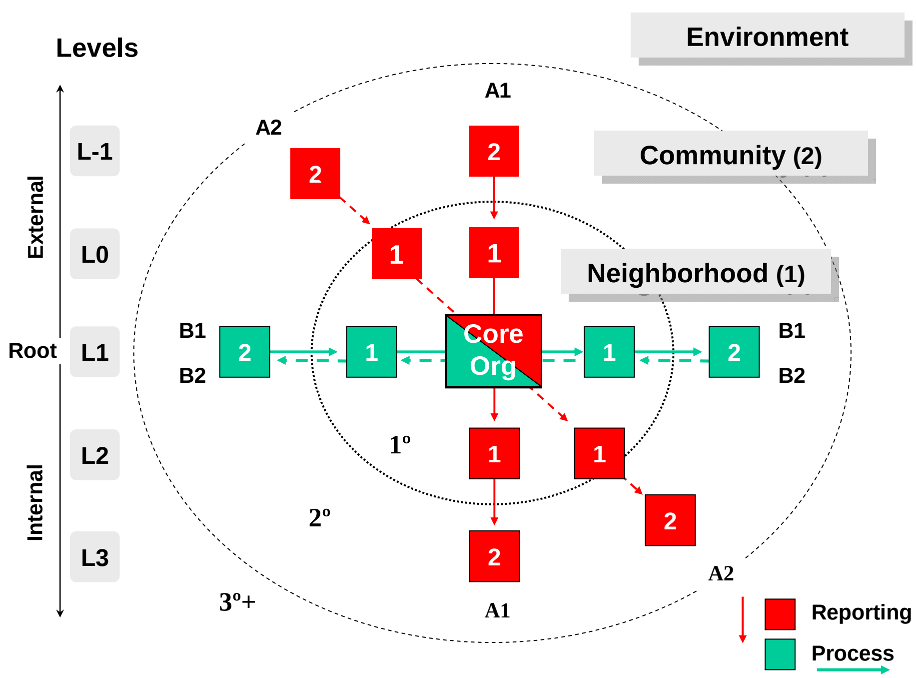
2. Community: Two Links Out

We look next to nodes two directed links away, nodal actors who comprise the local community.

Two links may be the "near horizon" of a complex adaptive network. We have noted before our anecdotal observation that people typically track connections one and two links away from themselves. Without tools to help, the multiplicity of people and positions three, four, or more links away becomes mentally unmanageable.

Neighborhoods are formed from close relationships, *immediate* connections with external people, positions, and organizations. Communities in turn include *mediated* relationships with nodes two links away. Beyond two links, the number of relevant nodes fades into a confusing blur. We label the endless habitat of unknown actors outside the local community an organization's "environment", three or more directed links away from a core member of the root network. These larger meshes in which organizations are embedded are summarized in Figure 5.

Figure 5: Neighborhood, Community, and Environment



As we reach out of the comfort zone of one link to include people two links away, we gain the "strength of weak ties." Mark Granovetter famously demonstrated years ago that key connections in finding a job came through friends of friends (two degrees of separation), not intimates (one degree) that tended to know one another. More recently, the small-world work of Watts and others has shown how these cross-group linkages reach beyond the tight clusters of inbreeding, dramatically shortening communications and decision-making paths for the whole network (see "Revolution in Networks").

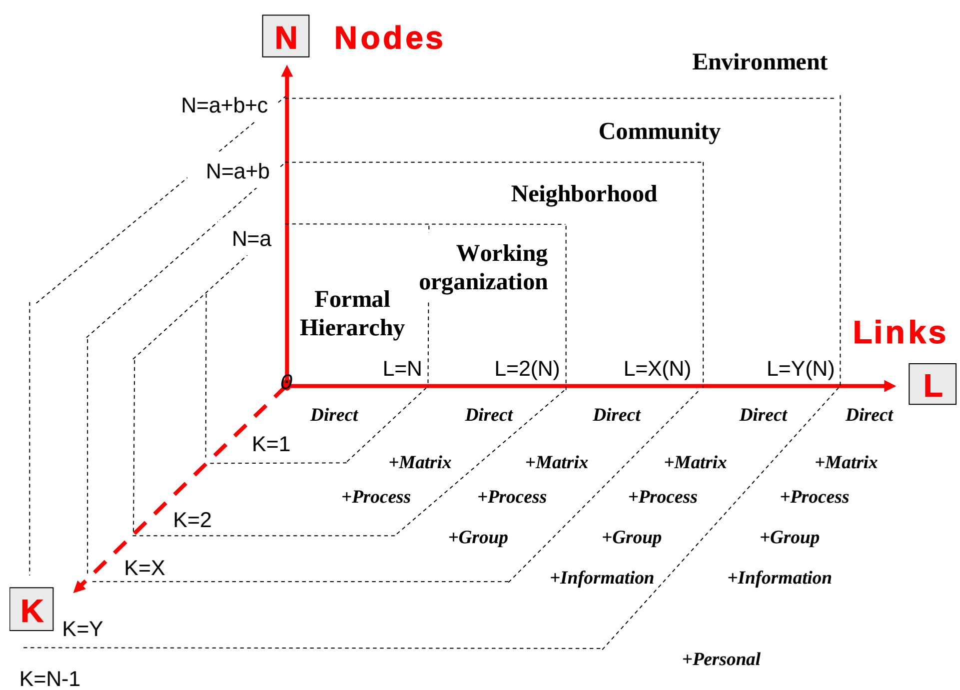
While we defined the core set of hierarchy positions as *internal* actors, we include a broadened perspective of organization units and groups as *external* actors. Indeed, external members in internal groups and internal members in external groups thread critical interdependent neighborhood and community strands across the organization's boundary.

Self-Organizing External Boundaries

An expanded view of boundaries one and two links away suggests more markers of self-organization, new relevant ratios of links to nodes, possibly new K-breakpoints beyond two. Self-organization is not just an internal process, but is also an interactive process, involving other organizations. All local organization species are together dynamically developing the local market landscape. An organization's piece of this dynamism is exercised through the other agents it touches and interacts with.

There is, we speculate, a K-value associated with an organization's one-degree neighborhood, a measure of the interconnectedness of a network and its neighbors. Too few connections and the organizations are just a set of independent operators looking out for themselves. Too many connections relative to the root of a particular organization may mean a neighborhood in chaos, one that is internally stressed and unable to find the minimal alignments between organizations, roles, and people.

Figure 6: Expanded K-Values (Speculative)



We extend the same reasoning to the larger ecology of relationships, and posit yet another distinctive K-value for a fainter community boundary at the two-link horizon from a given root network point of reference. This outer boundary, however, would be as murky and messy a line as the K-equals-one boundary is brilliant and sharp.

Who knows? We have taken only a few tentative experimental steps toward gathering neighborhood data and have no community node maps. So, this is just a speculative sketch of a more comprehensive theory of organization networks to be explored as people develop their own models. We combine these hypotheses into a single schematic that extends the organization network model from internal to external boundaries (see Figure 6).

This schematic fills out the network model for more ambitious organizational scenarios representing truly open systems. It gets us into a turbulent realm of dynamic dances between cooperation and competition.

Intelligent Collaboration

> *The promise of the new science of organization networks is for people to work together better. Not just incrementally better, but a step-change better.*

The story of human groups *is* collaboration, "people working together," the literal meaning of the word. Collaboration, co-labor, is the something more of human organization. People as individuals do not alone a group make; their interactions weave the single strands into an "us." Synergy is inherent in nature's networks, brought to life in human organizations by collaboration.

> *Collaboration is good organizational design in action.*

Organizational intelligence is today's leading edge of a fast-moving wave of change. A big leap up in human collaborative capabilities is possible, if not probable, based on the new digital-era technologies, most fundamentally and obviously represented by the computer and the Internet. Virtual communications and shared memory release our collective ability to collaborate from the limits of physical place and time. Virtual location and asynchronous time embrace a world of possibility, opening up vast new variety to everyone everywhere—for better and, unfortunately, for worse (e.g., terrorist networks).

The web burst forth as a still-accelerating explosion of pent-up connectedness between people that has been awesome—and shows no signs of lessening its impact on the ongoing drama of global civilization. The great tussle between the declining-but-still-strong Industrial Age and the emerging Information Age reached a decisive breakpoint with the release of the HTTP protocol and the first browsers in the early 1990s. A global giant cluster network of technologies and people formed. From the beginning, it was known simply as "the web."

We may be on the backend of the first inflection point in the meta-organizational leap. Every organization on the planet is now coping with, and using where possible, the expansion of possibility mandated by the technologies of the information era.

Organization configurations have no choice. They must adapt to the new environmental reality, or die. Being human, such adaptations are astonishingly varied. Indeed, as we enter the steep part of the ascendant curve of Information Age change, new organization configurations are both numerous and wildly different—a veritable zoo of network forms. We are in a Cambrian period of explosive innovation in virtually-enabled organizations. Simultaneously, there is a ferocious process winnowing these variants and selecting a few configuration winners to take us into our collective future.

Virtual time and place challenge us as members of groups of every size to adapt to the new possibilities. Hubs in the new network forms bespeak variety, but also the boundaries that point to the inevitable awkward point of tension between confining order and unconstrained chaos.

Smart money looks for intelligence to give evolutionary advantage, whether biologically or economically. As students of new forms of organization for many decades now, our bet is on smart organizations, intelligent collaborations, networks that think.

> *Ours is a time of historic struggle between emergent complexity and reductive simplicity. It will, we predict, be a victory of collective brain over brawn.*

For *us*, in small organizations and large, the lid is off variety. A Pandora's Box of catastrophic changes and awesome possibilities has opened with the current evolutionary acceleration—and may the fittest collaborators win in the Network Age.

Footnotes

[1] Harold Morowitz, *The Emergence of Everything: How the World Became Complex,* Oxford University Press, 2002.

[2] Murray Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex*. Henry Holt, 1994 (page 17).

[3] Arthur Koestler, *The Ghost in the Machine*. London: Hutchinson (1967).

[4]Jeffrey Stamps. *Holonomy: A Human Systems Theory,*. Systems Inquiry Series. Seaside: Intersystems Publications, 1980. As part of Jeff's *Holonomy* doctoral study many years ago, he examined all the broad-scope system theories—particularly those that included the human domains—to identify common patterns. He found that hierarchy in the sense talked about here, as levels or holons, in every systems theory then published. The ubiquity of the hierarchy principle has become part of mainstream scientific thinking, particularly in the biological sciences.

[5] Herbert A. Simon, "The Architecture of Complexity." *General Systems Yearbook X.* Society for General Systems Research (1965). Originally published: *Proceedings of the American Philosophical Society*, Vol. 106, No. 6 (Dec. 12, 1962), pp. 467-482

[6] We retell Simon's famous Parable of the Watchmakers with renamed Horus and Tempus as Sam Serial and Linda Levels in "The Innovators," in *Virtual Teams, 2nd Edition: People Working Across Boundaries with Technology*, John Wiley & Sons, 2000.

[7] Stuart Kauffman, *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*, Oxford University Press, 1995, page 83

[8] Stuart Kauffman, *Investigations*, Oxford University Press, 2000, page 49.