IT – Revolutions in the Industry:

From the Command Economy to the eNetworked Industrial Ecosystem

- Position Paper -

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Abstract-**This paper explores the transition from the command & control (C2) structure and culture of the traditional hierarchy – as backbone of last Century's Industrial Revolution - towards the eNetworked Industrial Ecosystem – as backbone for this Century's on-going IT-Revolution. Socio-cultural and economic contextual variables that may help or hinder the implementation of a heterarchical organization driven by responsible autonomy, are analyzed underlining the paradox hidden in the 'emergent' nature of an eNetworked organization. We illustrate how, within the classical 'top-down' managerial approach, the very power of initiative that can leverage 'bottom-up' clustering of resources to address dynamic organizational goals is hindered to conclude that a deep culture of trust and collaboration can unleash this power enabling the untapped 'mystery' of *complexity* to be used as a competitive advantage.**

Keywords. Organizational architecture and protocols, Complexity, Command and Control (C2), eNetworked industrial ecosystem, heterarchy, holonic swarm, policy change.

I. INTRODUCTION: ENTERPRISES AS INDUSTRIAL ECOSYSTEMS

Hardware to software to *Everyware* [Greenwood 2006] – the future 'Internet of things' will enable spontaneous creation of global enterprises as *ecosystems* merged seamlessly into a forever growing open market economy, in which dynamic adaptation and seamless evolution are equivalent to survival. In such "opportunistic industrial ecosystems" single devices / departments / enterprises become part of a larger and more *complex* infrastructure dynamically combining the individual properties or attributes of single entities to achieve an emergent desired behavior of the ecosystem [Ulieru 2007a].

To truly leverage and benefit from the advances in network technologies significant effort must be invested in transforming the design principles of human organization and to understanding the cultural and institutional implications of the mechanisms driving decentralization in the networked economy [Kurtz 2003]. The task (and plague!) of 'eternal transformation' that accompanies accelerating change and technological innovation calls for an ongoing demand to not only 'run the organization' but to 'change the organization' constantly making every effort to accommodate periods of extreme change [Walker 2006].

II. THE PARADIGM SHIFT: FROM HEIRARCHY TO RESPONSIBLE AUTONOMY

A. Hierarchy: The Organization-As-Machine

The 'machine-organization' that supported the industrial revolution resembles the type of military organization that emerged after World War II [Fairtlough 2005]. With its strictly engineered occupational structures it offers a 'top-down' designed rigid, highly specified division of labour separating the designer (CEO as 'king') from the 'tool' (organization), which in turn defines relatively linear, static career trajectories. By sorting human into internally homogeneous and hierarchical ranks, hierarchies create an internally *coherent* communication and decision chain for optimal efficiency to accomplish the tasks and missions for which the 'machine' was designed. Although labour is viewed as an input, the worker, as any other 'part', is replaced as needed. The purpose of the control hierarchy (command economy) is to ultimately enable a single individual (the controller) to control the collective behavior, but not directly the behavior of each individual. This implies that the collective actions of the system in which the parts of the system affect other parts of the system must be no more complex than the respective controllers [Bar-Yam 2003]. Thus, a hierarchical organization can only accommodate simple, routine individual behaviors (e.g. an army in training) and so it limits the complexity of possible collective behaviors of the system to *coherent* ones [Grobbelaar and Ulieru 2007]. Within this mechanical and linear causality is embedded a rigid determinism, in which a stable environment with little change promises consistent output. Thus control hierarchies achieve great efficiencies, economies of scale and great success within a relatively stable environment, with a well-defined product/output.

B. Heterarchy: The holonic enterprise

Trying to mitigate the span of control to that which an individual can effectively manage with more managers and correspondingly reduced spans of control is useful to the point where collective behavior required by the organization increases in complexity that is beyond the capacity of the highest level of the control hierarchy. To deal with an increasingly complex and turbulent environment a modular concept of organizational architecture was enabled by the IT revolution, namely the *holonic enterprise* [Ulieru et. al. 2002]. The concept of holons [Koestler 1967] enables the construction of very complex systems that are nonetheless efficient in the use of resources, highly resilient to internal and external disturbances, and adaptable and flexible in the face of changes in the environment in which they exist. It combines the best features of hierarchical ("top down") and *heterarchical* ("bottom up", "cooperative") organizational structures as the situation dictates. This concept can preserve the stability of hierarchy while providing the dynamic flexibility of *heterarchies*. As mechanism for balancing autonomy and cooperation, *co-opetition* mediates the collaboration in an ecosystem of decentralized holonic enterprises via a three-level coordination backbone.

C. The eNetwork enabled enterprise(Industrial Ecosystem)

For complex problems and rapidly changing environments (fitness landscapes) a different approach is required, one that allows more agile customization of talent and resources. We define an *industrial ecosystem* as a temporary alliance of enterprises that cooperatively works together to share skills or core competencies and resources in order to better respond to business opportunities - and whose cooperation relies on eNetworks linking interoperable distributed information systems. In such an ecosystem [Folke et al 2004] the partner enterprises are specialized to achieve both their own goals and those of the greater organization [Folke et al 2005]. Such organizations are characterized by: the participants' ability to negotiate between autonomy and cooperation in a drive (attractor) towards a common goal; a coordinated workflow process that triggers the formation of high-level organizational structure (patterns of collaborative clusters) through low- level interactions between participants; and a capacity to organize over spatial and functional scale [Walker 2004] to maintain resilience to the unexpected functional disturbances.

As *emergent* organizations [Ulieru and Unland 2004] industrial ecosystems go one step further by constantly monitoring their performance and the market in order to improve their overall efficiency, i.e., they permanently check whether there are (more) suitable possible partners available on the market which may either replace existing ones or add to the overall aim of the virtual organizations in a positive way. The similarity with Adam Smith 'invisible hand' by which the free market mechanism stabilizes prices through the power of individual buyers – is to be noted [deLanda 1997]. In the eNetworked ecosystem players behaviour is influenced by the organizational policies which act as 'invisible hand' to either unleash or to constrain the creative innovative power of the individuals in the organization.

The key characteristic of an eNetwork enabled enterprise fuelled by the NEOps concept is the ability to rapidly "pick, plug, and play" processes to configure for meeting an unexpected situation [van Heck 2005]. One might regard such a network as an *expectant web* of participants ready to jump into action (pick) and combine rapidly (plug) to meet the requirements of the specific situation (play) [Ulieru 2007b]. On completion, the participants are dispersed to "rest" while, perhaps, being active in other endeavours including their normal operations outside the network. In this regard eNetwork-enabled industrial ecosystems exhibit a *collective behaviour* much in the same manner as swarms self-organize to respond to an unforeseen problem [Bonabeau and Meyer 2008] by simple individuals interacting locally with one another and with their environment without centralized control. Emerging properties of the collective behaviour resulting from interaction between parts cannot be anticipated because it is not implicitly contained in the behaviour of the individual parts at a particular scale of observation [Holland, 1998]. Such systems can be modeled using the Multi-Agent Systems (MAS) paradigm [North and Macal 2007] where each individual is modeled as an agent and their interactions modeled as links. Thus a swarm equates a network of agents interacting intensely with each-other in generating a collective behaviour. A model for achieving this kind of integration, responsiveness and adaptability is the Network Enabled Operations (NEOps) [Enemo 2007] which was proposed to fulfill the needs of quick response required by military in today's unpredictable threat-prone environment. NEOps is defined as "An evolving concept aimed at improving the planning and execution of operations through the seamless sharing of data, information and communications technology to link people, processes and ad-hoc networks in order to facilitate effective and timely interaction between sensors, leaders and effects". NEOps enable emergency response organizations to self-configure 'on

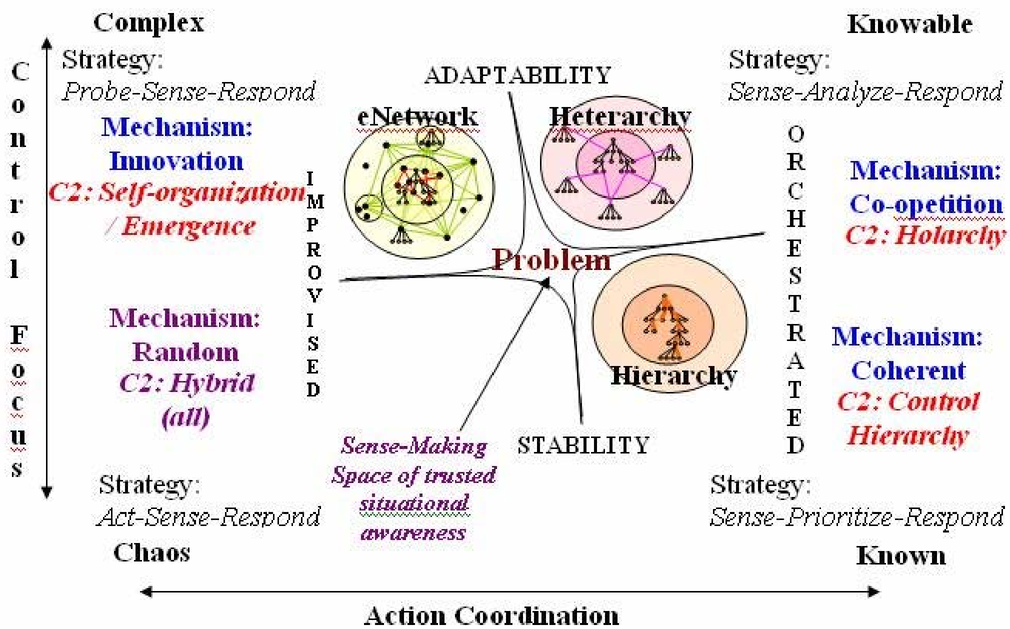

Fig. 1: Problem space relative to organizational structure that can address it.

the fly according to the particular dynamics of the crisis at hand for providing tactical, proportional response [Ulieru 2007b].

A snapshot of the contextual characteristics and types of problems addressable across the <hierarchy-heterarchy-network> organizational space is presented in Fig. 1 while Table I summarises their comparative advantages.

predominance of industrial control hierarchy as the design principle. The fundamental paradox about Web 2.0 technologies and the transition from hierarchical to the NEOps enabled industrial ecosystem is coined in the dilemma: "We've made substantial investments in collaborative technologies and people are not using the system to its potential. What's wrong?" The explanation is hidden in the fabric of the organizational structure,

TABLE I

GENERALIZATION OF RELATIVE ADVANTAGES OF DIFFERENT ARCHITECTURES

Organizational Architectures	Trust	Culture & Leadership	*Collective Thinking*	*Conflict Resolution*	*Autonomy*
Control Heirarchy Military Organization	Placed in process of execution	Centralized decision making emphasizing standardization and task accountability	Low	High	Low
Modular or Heterarchical Universities, Democracies, Consulting Firms	Placed in roles and occupants	Shifting leadership depending on domain; decision rights embedded in roles.	Medium	Medium	Medium
Responsible Autonomy Free markets, eSociety, First Rsponders	Placed in other's expertise	Collaborative within & across organization lines, norms – generalized reciprocity	High	Low	High

III. THE 'INEFFICIENCY' PARADOX

A key barrier in enabling network technologies to leverage the power of collaborative industrial ecosystems is the nature of the organizational and social architecture – essentially the

as explained in the following scenarios:

If an 'actor' from the traditional control hierarchy would approach an 'actor' in the eNetworked ecosystem (Fig. 2a) – the first question could easily be: "Take me to your leader!" with a

likely response of incomprehension, given that in the ecosystem every actor can become an 'emerging leader' depending on how a particular situation calls for his/her talent and action.

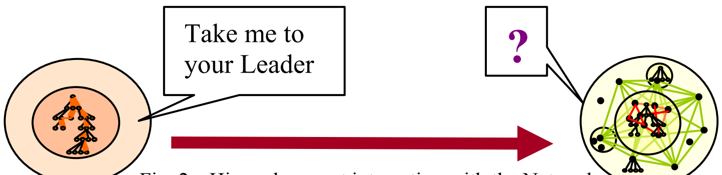

Fig. 2a. Hierarchy agent interacting with the Network

In the reverse situation, an actor from the NEOps ecosystem attempting to involve its talent in a hierarchical organisation would be immediately asked: "On whose authority are you acting?" or "That against the rules!" – definitely robbing the hierarchy of an opportunity to create a community exploiting the (puzzled) intruder's talent. What is needed to unleash the power of network technologies within and between organizations is the

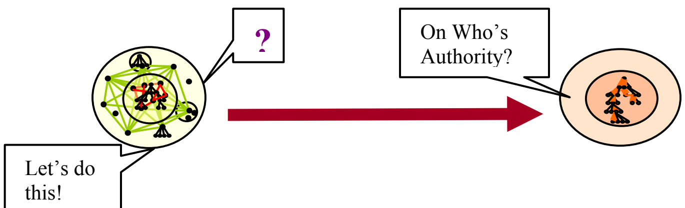

Fig. 2b: Network agent interacting with Hierarchy

integration of more responsive organizational architectures in order to initiate corresponding cultural change – in short creating a type of meshwork within the organization.

Command and Control (C2) is a term used mostly in association to military operations – however it extends beyond this domain to denote the structures and processes though which an entity (i.e., an organization, a system, an organism, etc.) operates. Much of the entity's C2 'logic' which drives the overall collective behaviour of the individual entities is often recorded in its constitution, by-laws, policies and practices manuals, or design documentation. As per Fig in the hierarchy C2 is the 'top-down' *decision chain*, in the heterarchy it is the balancing engine of *co-opetition* while in the industrial ecosystem it translates as an emergent dynamics of the associated network modeling the interactions between system's entities.

In transitioning from hierarchy to the network-enabled autonomy one has to face the paradox stemming from their radically opposite C2 mechanisms. A strong argument regarding the role of architecture and protocols in the evolution of complex systems - in particular in the capacity to develop resilience through robust structure is made in [Carlsson and Doyle 2002]. Protocols define how diverse modules interact and architecture defines how sets of protocols are organized. The concepts of architecture and protocol are completely compatible with the challenge of developing new ways to organize human effort beyond the classic industrial control hierarchy. In the idea of 'Intellectual Capital' [Malone 2004] there are three types of capital: Structural capital (owned by the organization); Human Capital (owned by individuals – leaves the organization when they leave); and Social Capital (an emergent arising from the relationship of individuals with each other (determined by the 'individual logic') and the organization (determined by the 'network logic'). One can 'tune' the social capital via appropriate policies enabling flexible group forming to leave room spontaneous innovative initiatives.

IV. THE HOLONIC SWARM MODEL

A mechanism for transitioning from hierarchy to autonomy via the holonic heterarchy was proposed in [Grobbelaar and Ulieru 2006]. In this model holon context is defined by their goals and the priorities associated with these goals. All goals are classified as either *intended* (individual holon goals) or *imposed* (on the holon by the holarchy). 'Priority ratios' of the intended over imposed goals are used to tune the degree of autonomy of individual holons in the holarchy. The intrinsic duality cooperation/autonomy creates a tension aiming to fulfill both the imposed and intended (desired) goal simultaneously as much as possible. This tension acts as an 'invisible hand' stabilizes the holarchy at a certain structure according to the ratios 'holon intended/holarchic imposed' goal as individual holons are either joining or leaving as they see fit with their individual goals, similarly to how buyers in the market decide to purchase a product or not and this stabilizes the prices accordingly. Adjusting the ratio to give priority to either the intended or imposed goal tunes the degree of autonomy of holons within the holarchy, thus spanning from total hierarchy to total autonomy. To put this model in practice in social organizations one has to envision a 'self-censoring' mechanism that would keep the independent holons aligned with the organization's purpose such that they can cluster around emerging goals that support the greater goal of the holarchy. We term this 'self-censoring' mechanism - *responsible autonomy* - that is, an individual or group has complete autonomy to decide what to do, yet is *accountable* (to the holarchy) for their action and outcome. The emphasis on responsibility as accountability marks the difference from anarchy in a responsible autonomy driven holarchy.

V. RECONCILING THE PARADOX

C2 can be built into the architectural requirements of an organization by determining the 'logic' of individual components as well as their interactions through protocols encapsulating the policies and governance rules, which thus will shape the structure and dynamics of such an organization. The division of labour determines the interactions between components. These in turn determine the network structure which plays an important role in constraining system behaviour. This points to the crucial role the C2 'network logic' (protocols and policies) have on either facilitating or obstructing collaboration across the eNetworked ecosystem. In reconciling the 'inefficiency' Paradox one has to enable the two paradigms "organization-as-machine" and "organization-as-complex-evolving-system" to work together. The use of Web 2.0 technologies to enable group forming networks and peer-production can power an organizational 'overlay' of a new type of *agile and fluid division of labour* enabling, a flexible C2 mechanism to leave space for the individuals to manifest their talents within the organizational ecosystem. The overlay organizational network is an emergent of the strategic choices, external context (such as the regulatory climate) and implemented organizational policies and operating protocols that 'attune' individual behaviour within the network. The purpose is to design these strategic choices and internal organisational policies and protocols in a manner that enables the individuals to 'get things done', either by distributing institutional complexity across larger numbers of employees or by focusing it in a few pivotal roles and mitigating it with strong capabilities in those positions. Tuning the protocols to enable use of the untapped human capabilities within the organization, generates a type of virtual layer that acts as 'invisible hand, leaving room for people to pursue their interests and self-select to contribute to projects that feed their interests, abilities, passions or curiosity in a digital division of labour, while continuing to fulfill the obligations of the traditional layer of occupational/operational jobs and work thus dynamically balancing autonomy and cooperation within the paradoxically opposite paradigms.

VI. Enabling the Analysis of Transformation

Let us suppose that Directors only 'owned' 70% of the time of each of the worker under their control, and ADM's/ Vice President's owned' 15% of the workers and finally each individual worker 'owned' 15% of the time that constituted their 'job' obligation. In this way Director/managers would be required to run the organization with 70% of the time of human resources under their control, while ADM/VP's would have 15% of the time of the human resources under their control to implement transformational work based on strategic requirements, and finally, each individual would have 15% of their own time to contribute to peer-production initiatives chosen on the basis of their own interests. This 15%, in conjunction with enabling network technologies would provide the organization with a market-like corporate-level resource pool, group-forming network, and peer-production [Verdon et al 2004]. With the allocation of a percentage of the worker's time to the VP and the individual comes the opportunity to not only work within the larger parent organization, but also with other partner, associated or strategically linked organizations and institutions that are important to the parent organization.

To enable the organizational transformation, using simulation modeling we are setting up a demonstrator enabling various similar 'thought experiments' on the various configurations resulted from the integration of network technologies, architectures of participation and peer-production. Repast agent simulation toolkit was chosen for its adequacy in modeling complex social systems and in particular due to its proven success in emerging trend prediction of complex interdependent systems [North and Macal 2007]. On this foundation we are building an artificial institution framework [Vasconcelos 2004] based on deontic logic [Sen and Airiau 2007] as mechanism for the dynamic deployment of networked ecosystems. The feedback loops internal to each organization are embraced by an overarching coordination feedback offered by the emergent organization network. This mechanism enables the simulations to 'surf' the complexity of the situation – illustrating which organizational compounds are most adequate to tackle it – and which policies can enforce the resilience of the networked ecosystem [Gibson, Lemyre et al 2007]. The Testbed will enable visualization of these paths in action via *profiling change processes* [Werther 2000] – pointing to the most appropriate course of action and meta-organizational configurations. The centralized command of a single supreme commander is distributed by the network across various local sub-groups clustered 'ad-hoc' - thus the network acts as a decentralized controller scaling the overall ecosystem into smaller resolutions / groupings. Perhaps not everyone would want to use this 15% of their own time, perhaps an individual would only find 5% maybe some other would need 20%. The simulations will enable us to visualize a way to explore how to create such a space and how it could be used to create and foster a culture that encourages collaboration and initiative.

VII. CONCLUSIONS

The transition from last Century's 'industrial revolution' (which focused on the single point of production in a 'command economy' acting on 'machine-like' rigid 'Command and Control' – C2 workflow) to today's 'industrial ecosystems', is marked by a constant drive towards production decentralisation [Kurtz 2003]. This transition has to break the rigid C2 backbone of 'top-down' control by enabling the 3rd 'C' (Communication – realized via eNetworks) [Ulieru 2007b] to unleash the power of an 'opportunistic' responsible autonomy allowing the organization to emerge from the 'bottom-up' together with its ever-changing goals in the market dynamics. While clearly holonic technical structures are feasible and in place [Tognalli and Ulieru 2005], the human/organizational command & control hierarchies can place rigid procedures that completely overlook the full potential of the information technologies. What is missing in this reliance on *autonomic pursuit of command intent* is something comparable to a 'price mechanism' that signals the information required for the (self) synchronization by the 'invisible hand' of the organizational network, similar to how the 'invisible hand' of the market economy was driven and in turn influenced the individual buyers through the dynamics of the price mechanisms [Verdon et al 2004]. Network technologies and informational transparency can provide the signalling mechanisms by which the holonic organization can self-organize in a market-like manner. And so perhaps as the 'organizational market' travels its last mile to penetrate the command & control economy of the industrial organization, the market itself becomes transformed by the intangible and tacit nature of knowledge into an *informational commons* allowing the holonic organization to be unleashed.

Ultimately the experiments with free time quantities acting as 'prices' in the market or as 'priority ratios' in the holonic swarm - will hint towards ***concrete policy making guidelines*** for a change of culture enabling organisations to fully exploit the advantages of a networked approach to increase their effectiveness. Organizations understanding how to harness complexity will be able to create new emergent value and capability, while becoming more resilient. To shift the culture, contributions and involvements have to be recognized within the larger organizational assessment regime. This would help to create the intense culture of collaboration that is beyond and outside of the protocols ingrained in the homogenated ranks of the traditional control hierarchy – the culture that is so striking in the story of the Toyota Aisin Crisis [Watts 2003].

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