Paradox of Control
in Complex Large-Scale Projects

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Abstract: The paradox of control is apparent in large scale operations trying to solve today’s complex challenges. Organizations are struggling to find effective control models to deliver the adequate results, and frequently experience contradictory and counterproductive outcomes from their control efforts. I will argue that our underlying principles for organizational control are still influenced by the remains of reductionism and positivism. On one hand, it introduces complexity, leading to slow decision making and time delays; on the other hand, it underestimates the complexity of the challenge in the environment, and seeks to apply control models that are too simplistic, without sufficient attention to the connections, interfaces, and boundaries. I have analyzed four comparative cases in two different organizations with two distinct different control models. Both organizations were dominant players in the oil and gas industry, delivering large scale projects with significant complexity influenced by technical, executional, cultural and regulatory factors. Five, propositions were crafted that presents a novel insight to how the paradox of control may be avoided by applying new principles for control. After presenting the research method, the propositions are first discussed related to the central findings in the four case studies. Second, comparisons to complex systems theory and organizational theory are made for each proposition. Third, enabling and limiting factors are investigated with basis in findings. The paper hopes to inspire a multi-paradigmatic approach to how new control paradigms can be informed by insights in natural complex systems.

Keywords: Paradox of control, social systems, complexity

INTRODUCTION

In the context of management and organization, the concept of control represents a variety of mechanisms that in general foster consistency, predictability, knowledge acquisition, and coordination in the pursuit of defined goals (Stansbury and Barry, 2007). Control makes cooperation possible, and enables production of complex goods and services. However, several factors challenge our ability to control; for example, the accelerated rate of change, interconnectedness among people and organizations, and seemingly random ‘disturbances’ create unintended and unimaginable effects. The aggregate of these factors is often referred to as complexity. Modern world challenges are increasingly complex, meaning that larger parts

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and systems in our society are interconnected. Our attempts to deal with these complex challenges require equally complex organizations (Ashby, 1958). In dealing with complexity, we are also witnessing more and more situations where inconsistencies and counterintuitive effects emerge (Handy, 1995), and where the ability to control the system to a desired result appears to be lost. The outcome is not only different from the intended result, but are often directly contradictory.

When critical functions of the society clearly demonstrate inadequacy to control their own outcomes, we experience a paradox of control (Streatfield, 2001). The paradox appears when the results are contradictory to the intended effects, and corrective actions from the controller only lead to increasingly counterproductive outcomes. There is a notion that the only way to regain control is to let go and stop controlling. This is not a logical paradox, to be solved by thought, but rather a paradoxical experience. An experience that is ancient to humans, stemming from the Greek *paradoxos*, meaning ‘contrary to expectation’, combining the word of *para*, i.e. contrary, and *doxa*, i.e. opinion (Merriam-Webster Dictionary). It is also an experience that challenge our a priori notion of causality, and fundamental epistemic principles, where being and non-being cannot exist simultaneously. Throughout history, the paradoxical experience has lead people to frustration and apathy (Braathen, 2017). People lose faith in the system, and in our society’s ability to control our destiny and provide certainty for the future. I therefore, believe there is an urgent need to think differently about control in management and organizational theory.

The general understanding appears to be that, as our world is becoming more complex, the future of management and organizational theory must depart from static perspectives to arrive at frameworks integrating dynamics and evolution (Anderson, 1999; Stacey, 2011). Insights derived from properties of natural complex systems may be explored, where concepts as complexity, adaptability, and dynamics are central (Arthur, 2014). Natural complex systems are found at all levels in the world around us, from the physical system of a river, to biochemical systems in the cell, to bodily systems, to cultural systems. Natural complex systems do not experience any paradox of control, and their control model is perfectly in harmony with the objectives, the function and role of the system. My hypothesis is that these natural complex systems can guide our design of control models in modern organizations.

The topic motivated the study’s key research questions; i.e. what are the key factors in our current control philosophies that lead to the experience of a control paradox? How can we incorporate insights from theory of complex adaptive systems to formulate new principles for control in organizational and management theory? To investigate the questions, I analyzed in-depth data from four case studies in two multinational organizations performing large scale, complex projects in the oil and gas industry. The case studies provided an opportunity for comparative analysis to identify key issues and drivers. Further, to integrate insights from the case studies, with existing organizational theory and theory of complex adaptive systems.
In this paper, I will first, briefly describe two key concepts; i.e. a paradox of control as an instance of a social paradox, and further, how any organization should be seen as a natural complex system. Second, I will discuss the fundamental and underlying epistemic principles that influence our current control models, and how they differ from a natural complex system perspective. Third, I will describe the method and the findings from the comparative and longitudinal case studies. Fourth, I will present the main findings from the study. Finally, I will present and discuss a set of enabling and limiting factors to the findings.

THE PARADOX OF CONTROL

The paradox of control is a social paradox, different from paradox found in logic, or rhetorical paradox found in arts and literature (Braathen, 2016). Social paradoxes are not logical contradictions per se, but rather comes in the form of more general tensions and oppositions between incompatible positions. People in social systems, as an organization, experience counterintuitive and inconsistent phenomenon and feedback, that appears to be interrelated and simultaneously contradictory. Unlike their logical siblings, the social paradoxes do not exist independent of time and in abstract thought, however, is an experience subject to the temporal and spatial constraints and influences of the real world (Poole and van de Ven, 1989).

Studies and literature on paradox in organizational and management theory have recently developed significantly (Schad, 2016). The paradox perspective explores how organizations can attend to the dynamics of simultaneous competing demands, and hence, represents an alternative to more traditional contingency theory (Lewis, 2000). Oversimplified, reductionist and static analysis have so far brought incomplete theories (Schad, 2016), whereas natural tension emerging from balancing forces, will require understanding of dynamics, evolution and change (Smith and Lewis, 2011).

I will argue that the paradox of control is a type of social paradox described as a learning paradox (Leonard-Barton, 1992; Braathen 2016). A learning paradox may emerge when beliefs or assumptions of an organization fail to keep up with the external changes (Cannon, 1997). An organization may face increased environmental complexity coming from (global) developments of interconnectedness, competition, and disruptive innovation. On the other hand, the organization has developed its own belief system based on knowledge categories, structures and culture. This belief system is the foundation for the control model of the organization. It is within this model that events from interactions with the environment are observed, interpreted, and connected to existing understanding. It is from this model corrective measures are taken to compensate for deviating feedback.

The learning paradox evolves as the incomplete, and too simplistic model, inadequately interprets observations from the interactions with the more complex environment (Braathen,
2016). The organization’s own belief system appears to be inconsistent and may be perceived, directly contradictory. The organization is not experiencing any ontological paradox in the environment, but is rather exposed to cyclical dynamics in its own belief and control system, in the form of a ‘limit cycle’ (Braathen, 2016). Acting upon a phenomenon in the environment that once corresponded to a well understood category, may suddenly lead to contradictory results.

THE ORGANIZATION AS A NATURAL COMPLEX SYSTEM

Nature is full of complex systems; anything from physical structures of atoms and molecules, biological systems in the body, the mind, the society with its cultures. By studying nature’s complex systems, we learn about fundamental features of complexity, of evolution and dynamic change. These features are significantly different from our reductionist approach to organizing, where we break down a complex issue into mutually exclusive and collectively exhaustive elements. The fundamental difference is that a complex system shows properties as a whole, that cannot be reduced to the variety of its parts, but rather exist because of the relationship and interaction between them. If we break the system down to its parts, we will be able to describe and observe valuable insights about the parts, however we will miss the opportunity to understand the interaction between them. When we talk about complexity, we must address both; i.e. complexity comes both from the variety of parts, and the interaction between them.

Even though an organization is a result of human design, it has also a natural complexity. The organization contains a number of heterogeneous individuals, systems and structures. Individuals interact, communicate, and put a variety of competence and perspectives into action. People interact with systems, and systems interact with other systems. A set of interactions may be random, or may follow a certain pattern. A pattern of interactions creates a system that we may call stable if it is reoccurring and is self-maintained. Stable patterns of interaction are what we in management and organizational literature call routines. Stable systems of interacting routines will again form capabilities (Winter, 2013).

The interconnection occurs both in a spatial and temporal dimension. Individuals and routines are spatially interconnected as a result of their physical location and topology of an organizational structure. They communicate face to face, through emails, or by using systems as mediating structures and organizational ‘memory’ with symbolic coded information. They engage in formal and informal interactions that may strengthen the relationship between them. On the other hand, their temporal interconnectedness relates to the function they play and to the temporal relationships between the different functions in the organization. This may include horizontal capabilities that participate in a process where a set of results must be produced in a particular sequence. The temporal relation may also be found in a vertical dimension between the different levels of the organization. Certain capabilities on a higher
level, require output as a result of interactions between a set of routines on lower levels, before they can take place. As an example, a strategic change on the senior management level will require a complex set of interactions, decisions and results, within and between the levels below. The change is a complex set of interactions that need to follow a sequence and topology of decisions in order to have the right properties on the overall level. The interdependence of the variety of actions on different levels, create a temporal complexity that are naturally sensitive to delays.

In general, an organization as a natural complex system evolve through an underlying mechanism of complexification. Constantly, new variety from interaction, communication and exchange of beliefs are created, and related to existing knowledge, symbolic representation and cultural expressions in the organization. This evolution does not take place in isolation, but rather in environments with other complex systems that co-evolve, that further drive complexification in a re-enforcing cycle (Braathen, 2016). The different levels will evolve in parallel with mutual influence on each other. It is natural and apparent to most people, that our society and its institutions and organizations, private and public, are exposed to this co-evolving complexification.

(FUNDA)MENTAL MODELS OF CONTROL

From the discussion above, I have described the two fundamental concepts in my investigation. First, a learning paradox that emerges as an organization confronts an environment of increased complexity with a control model that interprets that complexity inadequately. Second, the organization as a natural complex system involved in evolution as a constant and ongoing complexification process. I will argue, that this implies that the current way of thinking about control in management and organizational theory, is too simplistic, and may lead to paradoxical situations when exposed to an increasingly complex environment. I will now go on to discuss four of these underlying and (funda)mental principles of control and how they relate to our understanding of natural complex adaptive systems.

Controllability and the principle of requisite variety

The first assumption I will address, is the grounding belief that we have the ability, the means, and the tools, to control behavior, actions and outcomes in a modern organization. Examples of these control tools can be policies, processes and procedures, financial models as budgets and reporting, project execution plans and reporting, key performance indicators (KPIs) and key performance objectives (KPOs), balanced scorecard systems, management and quality control systems, and more. These models all have in common that they follow the reductionist logic of breaking down a whole into an exhaustive set of smaller mutually exclusive parts. The models can be quite extensive, detailed and comprehensive, based on a general assumption
that the more we break down deliverables and activities to a detail level, the better we can observe, measure and compensate any deviation.

The complexity of a system needs to match the complexity of its environment in order for it to survive. For example, the existence of a capability or routine is based on its ability to serve a function, by reliably producing a result valuable to another capability or routine. Hence, its complexity must be such that it can compensate for an adequate number of challenges from the environment. In principle, it is possible for all the parts to interact with each other, and the corresponding state space will span the total set of actions the system can perform. However, the function that the system serves, will likely bring it to produce a specific and limited set of outputs in order to maintain its functional fitness relative to its environment. Certain sets of interactions will be selected, and will restrain the number of actual states from the possible number of states that the system can take. The system will develop a repertoire, i.e. the set of results it may produce to uphold its function. When the complexity of the environment increase, the requirement for an expanded repertoire increases proportionally. Increased repertoire means higher ability to respond to different situations, however, longer time to search through all possible actions to find the adequate action for a particular situation. This is a tradeoff.

This fundamental understanding was developed by Ashby in his ‘Principle of requisite Variety’ (Ashby, 1958). Ashby states that in order for a controller/model to control something, it must have sufficient internal variety to represent it. For example, in a choice between two alternatives, the controller must be able to represent at least one distinction that creates two adequate possibilities. The repertoire of the controller must be at least as nuanced and complex as the system it is attempting to control. This means that the variety that the controller possesses provides an upper bound for the variety of what can be controlled. Further, that the larger the variety of actions available to the controller, the larger the variety of challenges from the environment it is able to compensate for.

In a modern organization connectivity between the individuals is growing exponentially with the development of infrastructure and digital technology. Further, more and more work is knowledge based. New variety of distinctions and categories are constantly being generated in communicative interaction inside the organization. Since the ‘reactant distinctions’ are products of mind and communication, they are not bound by the constraints of the physical world, and the complexity increases exponentially as variety is being produced in communicative interaction in networks of actors.

In theory, the controller would need to observe and represent distinctions for all the possibilities that we want to control. Historically, an activity meant a physical action, e.g. transportation of a pipe from one location to another. This is a type of distinction and action that is possible to both represent by a distinction in a plan, to observe, and to compensate for if not performed. Research and development, design processes, education of a child, are not of
this nature. First, distinctions may not be represented in the model as they are not a priori available, but constantly being created, and may emerge in the process of development. Second, many distinctions are not observable to the control system as they are internal to a coupled system and closed to the outside world (Luhman, 1995), e.g. a feeling of security that resides in the patient, or the general maturity for a child to learn specific topics. Third, the distinctions that are represented in the controller appear to be the same, but are not identical to the distinctions held by the system. This is in particularly true in knowledge intensive industries where we cannot ensure objective criteria of sameness and true identity (Braathen, 2016).

Fundamental understanding of what complexity is, how it is represented in modern organization, in combination with Ashby’s law of requisite variety, should caution us to believe that we can control behavior in an organization. When we try to apply control without being able to represent nor observe the adequate distinctions, we may unwillingly guide the system to an undesired and contradictory outcome.

Reductionism and Departmentalism

The next assumption is deeply rooted in our way of thinking and underlying most development we have seen in science, technology, societal institutions and organizations. This is the principle of reductionism with both ontological and epistemological consequences. Reductionist ontology would claim that a phenomenon as a whole can be broken down to a minimal, mutually exclusive set of parts. Equally, the epistemic perspective would provide explanations in terms of even smaller entities; i.e. theories, concepts, methods that would in sum describe the overall phenomenon. The philosophical foundation is built on the pre-Socratic atomist world-view, dominating western thought and scientific development.

The atomist and reductionist perspective has carried over into organizational theory and practice, and coincides with another fundamental understanding regarding the need for specialization and division of work. The principle of specialization is unrelated to the reductionist paradigm, as we also find this principle in process philosophy, evolutionary theory, and in complex systems theory. However, the two principles combined have led to a departmentalism in organizations (March and Simon, 1993). On one hand, departmentalism could be process oriented, where the desired outcome of the organization is broken down into main tasks in the overall process, and where activities are grouped by function or competence. Examples of this may be finance, procurement, engineering, and is described by Gulick and Urwick as departmentalization by process. The other principle of departmentalism is departmentalization by purpose; i.e. grouping activities by product line, customer segments, or by geographical territory (Gulick and Urwick, 2004). In general, departmentalization by process exploits the potential for economies of scale through specialization, while
Departmentalization by purpose leads to greater self-containment, improving internal coordination, flexibility and independence of central control.

On one hand, our underlying reductionist perspective would tell us that an overall phenomenon, as for example a market or an engineering problem, can be broken down to units on a lower level (e.g. market segments, competence as engineering disciplines), and that the sum of these units equals or answers to the overall phenomenon. On the other hand, a proponent of a systemic perspective would value the variety and description of the units, but claim that the function of the overall system is equally determined by the interaction and connection between them. This is not binary, and organizational theory and practice have developed structures that integrate both. Matrix organizations, teams, and networks are examples, created to compensate for silos of departmental actions (Drucker, 1999). These connections are increasing the complexity inside the organization, and hence, increasing the repertoire to respond to a more complex environment.

In my study of large complex projects in the oil and gas industry, the complexity of the environment increased significantly with, among others: higher requirements from rules and regulations, changed customer demands and market dynamics, and cultural differences in new construction and operational territories. Inside a departmentalized structure, the units tried out other connections or added variety; e.g. seeking cooperation between engineering and construction, or adding additional competence to the engineering division. Through these new connections, the organizations attempted to create new capabilities that would respond to a new and more complex market situation. This additional complexity increased the repertoire, however, also presented more alternative actions that had to be evaluated, and hence, slowed the processes, leading to time-delays, inability to deliver, and a feeling of lack of control. In addition, the function that a specific unit served would be less clear and of less value as it did not conclude a specific output. The natural response was to apply more control and coordination to compensate, leading to more complexity and problems.

In a natural complex hierarchy, the functional fitness is crucial to uphold the existence of the unit. From an evolutionary perspective, functional fitness addresses the ability of the unit to serve a function valuable to others in its external environment. This is a consequence of the unit’s structural fitness, given by the internal stability and constituency, which refers to the ability to uphold its structure when exposed to perturbations. Further, it refers to the strength of the connections between the sub-units, where a strong connection may stem from frequent interaction, or the quality of the interaction due to for example spatial proximity. Evolution would seek out new connections, new configurations to continuously remain functionally and structurally fit. In nature, we find that the structural fitness is higher on the lower levels of the hierarchy than on the higher levels. It is easier to separate a flock of birds, than to separate different organs in a bird’s body, and so on. This is equally valid in an organization. For example, the structural fitness given by the relations and connections in a small team, are usually stronger than in a global capability on a corporate level. Factors, relevant to structural
fitness could be for example geographical distance, time delays, quality and frequency of communication, and aligned incentive structures.

A natural complex system will drive towards a nested complex hierarchy of functionally and structurally fit units (Holland, 2014). The system would seek to reduce complexity by dividing work naturally into functions that maximize fitness (Simon, 1962). This would more often be contrary to principles of reductionism. In the reductionist departmentalized approach, increased complexity required internal complexification processes. The complexity from new interfaces were increasingly difficult to control, and transformation into new configurations may require more than continuous reconfigurations. It may demand a disruptive change of the entire structure and endanger the organization’s overall ability to survive.

*Continuity vs. Emergent Logical Levels*

A natural complex system may be observed and controlled on a level L even though observability and controllability is limited on the level below L-1. For example, I can control the transition of water being poured from a bottle into a glass, without have the slightest idea about the angular momentum of the water molecules. I can also control the number of new products released without knowing anything about the creative innovation process behind it. This is a perspective of scale, and a recognition of the value of observability of the different qualitative properties emerging on different levels of the system.

When hierarchies form in natural complex systems, each logical level emerges with a new set of properties that are qualitatively different from the level below. Hydrogen and Oxygen interact and form water. Water has fundamentally different qualitative properties; i.e. it is liquid, the source of life, the sea, rain, etc. Water is part of a cell, an example of life, and so on. The nested hierarchy of logical levels with different properties extends to bodily organs, systems of organs (e.g. cardiovascular system, nerve system), to the mind, to the individual, to social groups, to society, to culture, to the planet’s ecosystem. On each level, we need to rethink and restructure our strategy of control to address the adequate properties of the system relevant on each level.

As for other natural systems, complex social systems of organizations of any type, shows the same type of characteristics. The individual possesses physical, cognitive and emotional qualities as a result of an embodied mind. When we expose this individual to interactions with another individual, we may find qualitatively different properties as for example affection, love, anger, disappointment etc. Further, we know that when we bring a group of people together, a certain atmosphere in the group will emerge, impossible to predict, and qualitatively different than the mere aggregate of the people present. A larger group of people may form a culture that becomes deeply rooted in people's belief systems and influence how they perceive and interact with the world around them. Hence, the difference for example
between a student, the student teacher relationship, the classroom, the school, the local educational system, and the national educational system, will have significantly different qualities on each level. Similarly, any large organization will reveal different logical levels with emergent properties that are qualitatively different on each level.

Hence, it is not a continuous fitness landscape for control through the levels of a nested complex hierarchy. On the contrary, it is a discontinuous landscape for control between one logical level to the next. The dimensions of the fitness landscape on level L are qualitatively different than the dimensions of the fitness landscape on level L+1. The emerging new properties will add additional degrees of freedom to the state space of the system on the level above. For a controller to be meaningful and relevant on a particular level, we need to create distinctions that are adequate and relevant to the qualitative properties on that level. We cannot apply a mere aggregate of states from the level below.

In typical project management and control, we break down the overall project into major focus areas. Then we break down these areas into sub-areas, and so on. The project plan of a large oil and gas project could easily be five to seven levels with tens of thousands of line items on the lowest level. Even though the project plan is organized as a structured hierarchy, the levels in the project plan would more often fail to reflect the qualitatively different properties of the levels in the natural complex system it is trying to control. Natural functions representing a new emergent level would be distributed in the project plan, and hence be part of a structure that looked ‘continuous’ to the controller, i.e. the project management. As an example, a particular technical system, serving an important function in the overall solution, would emerge as a consequence of equipment and products connected and assembled. The system would possess properties and qualities that is different than the sum of the equipment. It may be used in a larger market, it may be used in multiple projects, it may be the start of a new technology development process, etc. However, in the project plan the structure may follow the process of engineering, procurement and construction, and hence miss the aggregated ability to observe and control these properties on the level above, i.e. the system level. Hence, the organization at an overall level could potentially miss the opportunity to develop, for example, modular and repeatable delivery of systems, enhanced organizational learning and cost efficiency, new R&D opportunities.

The qualitative properties on the level above could assist the project management, acting as a controller by restraining the potential variety. In order to uphold a particular quality, certain constraints need to be enforced on the variety and repertoire on the level below. Further, possible perturbation coming from for example a drive for optimization, vendor influence, or miscommunication must be compensated for. As such, the project management may integrate the properties to utilize as vicarious selectors in the evaluation of possible perturbation and requests for variations (Heylighen and Campbell, 1995).
Positivism

The final (funda)mental principle to be discussed in this article is our underlying heritage from positivism, and how it influences our design of control mechanisms, more specifically our systems and tools for control. Positivism is a philosophy grounded in the empirical world view where knowledge and understanding of the world can be observed with objectivity and value-neutrality, free from personal interests and subjective interpretation (Sletnes, 2018). Even though positivism in its purest form has been abandoned by many scholars in organizational and management theory, we still find remains of its heritage, also in neighboring disciplines as economics, political science and sociology, and I would argue that the positivistic belief system still plays an important role when designing control systems for organizations today.

The underlying assumption is that we can observe reality in the organization and its environment, and that our observations and representations hold universality among individuals and groups of individuals. In practical terms, we believe that we observe and communicate about the same phenomenon. Further, that our symbolic representation in structures and systems connect us, and equally represents this ‘sameness’. From a natural complex systems perspective, this may be perceived different. Phenomenon observed and expressed are part of a closed and self-maintained stable system of communication and interactions, where the true identity of a distinction drawn from an observation is closed off to the outside world. This holds true for an individual as well as for a social system.

I believe this perspective is commonly observed on an individual level. It is a common experience that different individuals hold different interpretations of the same particular phenomenon in their shared environment. The human ability to draw a distinction may be physically and biologically equally distributed, however, the recursive enrichment of distinctions and how they relate to each other, are specific to a particular individual and the interaction she has with the environment (Luhmann and Rasch, 2002). Over time the distinctions and connections evolve into more complex categories and perspectives that show heterogeneous properties belonging to the individual. In a communicative interaction with others, a mutual ground for understanding and shared mental frames evolve. Codes and symbols representing the categories are exchanged to create a shared meaning. However, it is common to discover that the distinctions and categories appear to mean the same, but the true identity is different (Günther, 1967). The true identity is closed off and internal to that individual psychic system only.

A social system as an organization, does not have the same cognitive abilities as the human mind. However, a social system will show cognitive abilities over and above the mere aggregate of the constituent actors (Leonartowicz, Weinbaum, Braathen, 2016). A social system may develop a shared set of categories held by the system itself (Luhmann, 1995). These categories represent the system’s ability to observe and interpret its environment, and reduce the complexity of a phenomenon in its surroundings into a model based on its categories. The categories evolve as distinctions are being drawn in interactions between the
actors of the social system and the environment, and further through interactions between actors (and systems) inside the social system creating connections between distinctions. This process creates a cognitive membrane, a boundary between the social system and the outside world, and implies that the codes and categories are closed to the environment (Luhmann, 1995). As for individuals, the codes and categories appear to be the same from the outside and in the interactive communication, however, the true identity of the meaning can only be experienced and described from the inside of the system. The relative difference between the ‘shared sameness’ and true identity of a category may differ with the complexity of the category itself. The category, ‘4’, is less complex than the category, ‘precise’. The degree of complexity depends on the connective value that this category has with other distinctions, and whether the category is in fact already a complex system of related sub-categories. This corresponds well with our practical experience of numbers as an objective representation of an observation.

The implications, contingent on this world view, for our philosophy of control seems to be substantial. First, in practice, comprehensive and far reaching control systems of prescriptive processes and procedures are developed and implemented with the underlying assumption that the true identity for all parties are similar, and the intention corresponds with the outcome. Second, the requirements for documentation and reporting is increasing significantly, reflecting the belief in observability and the true identity of its representation. Third, more often these control mechanisms lead to paradox of belonging on both an individual and on a group level (Smith Berg, 1987; Braathen, 2016). Internal categories in an individual appear to be the same as the category held at the group level, however, the true identity remains revealed and leads to a simultaneous experience of being and non-being. This paradox equally manifest itself on a social system level between a smaller social group and the larger organization it is part of.

METHOD

I performed four case studies to investigate the role of control in large scale projects. I followed and observed the cases over a five-year period giving a possibility for in-depth data and novel insight into the patterns of perceptions, communication and decision making in each case. Comparing across four distinct cases surfaced differential causal relationships between organizational design, management control philosophies, and actual outcomes.
Research Context and Case Selection

In his recent book Industrial Megaprojects, Edward Merrow studies projects with budgets over $1 billion (Merrow, 2011). In his analysis, projects within oil and gas industry have a central role and shows particular bad performance. Project cost over-runs were documented to be 30-40% on average, and schedule over-runs equally around 30% (Reid, 2016). Further, and perhaps more alarming, was that 75% of the projects failed to deliver to expected business results; i.e. results according to expectations developed and used as control models. The organizations involved are equipped with state of the art project management systems, highly competent personnel, and sufficient resources to deliver the projects, and yet, the efforts to control the projects seem to be consistently failing and almost ‘counterproductive’ to the intended expectations.

In my investigation, I chose four cases from the oil and gas industry where I could study extraordinary large and complex projects. By choosing cases from the same industry, I sought to minimize the variance of the context. The following drivers contributed to their complexity. First, the technical complexity; i.e. the actual solution being developed, with engineering of highly interconnected systems, technology and equipment; extensive supply chain management; and management of massive physical construction projects. Second, the cultural complexity; i.e. the work performed at different continents, in different cultures, time-zones, and languages. Third, the operational complexity; the units are situated in a diverse set of geographical areas, with different rules and regulations, and with both international and local requirements. Finally, the value chain complexity; i.e. interconnectedness between the financial construct, the technical solution and the operational set-up, demand a cooperation between multiple international players, and lead to extraordinary complex value chains.

Table 1 shows an overview of the cases selected with corresponding properties. Three of the cases were strategic business units within the same Fortune 500 corporation, adhering to a similar, but innovative project execution and control model; i.e. INDUSTRIAL A, INDUSTRIAL B, INDUSTRIAL C. The three cases would be investigated and compared with another publicly traded global corporation with a more traditional project based execution and control model; PROJECT A. The case selection provided an opportunity to conduct a comparative case study between two distinctly different organizational control models that had demonstrated different outcomes and results. The cases were chosen as ‘the extreme situations and polar types in which the process of interest was transparently observable’ (Eisenhardt, 1989).

The first case (PROJECT A), served as an example of a typical project delivery organization. PROJECT A is a publicly listed company delivering offshore oil production solutions, called Floating Production Storage and Offloading (FPSO), in a lease and operate model. The company was one of the world’s leading players in the FPSO industry. The organization was competence centric with a process based departmentalization; i.e. business development and
project definition, engineering, procurement, construction, commissioning, installation and operation; and PROJECT A would also provide financial schemes to allow leasing contracts to oil companies with both bare-boat and operational charters. In spite of the apparent accomplishments, the company experienced constant cost and schedule overruns in their projects, and at the time of the case study at PROJECT A, the average cost over-runs were 30\%, while the average schedule over-runs were 12 months. The failure to deliver on time and on budget would hurt profitability and consequently shareholder return. A similar development could be found across the main players in the FPSO market segment, that more or less followed the same business process with a similar approach to project execution and control.

The three other cases (INDUSTRIAL A,B,C), were strategic business units within a global corporation delivering solutions to various parts of the oil and gas industry. The project execution and control philosophy were built on the same platform and principles across the business units, even though the solution scope and industry segments varied among. My initial hypothesis was that the organizational structure bare more resemblance to a natural complex hierarchy and control system. The cases were selected to comparatively investigate how differentiated categories between PROJECT A and INDUSTRIAL, could enrich the understanding of how properties of natural complex systems may inform our design of organizational control systems. INDUSTRIAL had shown extraordinary results in the industry, proving the ability to reduce cost overruns to less than 5\% and schedule overruns to less than 1 month for comparable type projects. Further, the margins and profitability had increased significantly resulting in favorable shareholder return, while the volume of solutions delivered multiplied with a factor of ten over a decade.

*Data Collection and Data Analysis*

Data collection lasted for 5 years and included observation, participation, interviews, and archive material. In the first two cases, for PROJECT A and INDUSTRIAL A, I performed a comparative case study and methods for data collection was based on interviews, observations, and archive material. Next, in the following two cases, INDUSTRIAL B and INDUSTRIAL C, I participated under an action research paradigm. Again, the methods for data collection was based on interviews and archive material, as well as active participation in numerous workshops and meetings on all levels in the organization. Finally, interviews were also performed with oil companies that heavily influence and define the rules of engagement and the total control regime of a project.
I conducted 153 interviews with 89 distinct informants. I interviewed both senior management on the corporate level, senior management in the strategic business units, and managers and employees in pivotal roles inside the strategic business units. The interviews lasted from 45 min to two hours. Due to the strategic sensitivity of the issues, and in order to convey trust and motivate accuracy, I did not record the interviews, but took extensive notes. I observed and participated in a total of 42 senior management meetings, and 87 workshops with different teams inside the organizations. I had the opportunity to speak with executives in the workshops and during time in between to verify my observations and inferences.

I have had access to a large number of archive documents that provided rich insights to business strategy, project execution models, organizational structures, project plans, various types of reporting, and more. Further, information from websites, industry experts and analysis allowed me to triangulate my understanding, and the ‘triangulation made possible by multiple data collection methods provid(ed) stronger substantiation of constructs and hypothesis’ (Eisenhardt, 1989).

The longitudinal nature and the sequence of the case studies over the five-year period was crucial to the overall research design. The intent for my research was theory building, bridging theory in organizational theory with theory in complex adaptive systems. As described by Eisenhardt, ‘theory-building research is begun as close as possible to the ideal of no theory under consideration and no hypothesis to test…Thus the investigator should formulate a research problem and possibly specify some potentially important variables…. A priori specification of constructs can help to shape the initial design of theory building research…(hence provide) a firmer empirical grounding for the emergent theory’ (Eisenhardt, 1989). The first case study in PROJECT A was based in a grounded theory approach, while at the same time being conscious of documented variables in traditional project management in

<table>
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<th>Case</th>
<th>Srn Mngmnt</th>
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<th>Total Interviewees</th>
<th>Total Interviews</th>
<th>Snr Mng Meetings</th>
<th>Workshops</th>
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<tr>
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<td>15</td>
<td>22</td>
<td>36</td>
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</tr>
<tr>
<td>INDUSTRIAL C</td>
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large scale projects, and industry practice within the oil and gas industry. The observations were further guided by an epistemic framework of categories and properties found in theory on complex adaptive systems. Hypothesis and principles were crafted from emergent insights derived iteratively from triangulating multiple data collection processes.

Subsequently, I turned to a similar exercise in INDUSTRIAL A. An iterative process was conducted combining insights from empirical derived categories with constructs from organizational theory and complex systems theory. Consistent with comparative multiple case research, I followed up with a cross-case analysis where insights derived from the PROJECT A case were compared with the case of INDUSTRIAL A. Categories and dimensions from the comparative case studies were analyzed for similarities and relevance with respect to theoretical concepts in complex systems theory and in organizational theory. Significant discrepancies and agreements were noted and analyzed further.

The next step in the overall research process was to investigate how these principles apply to other organizational units. Multiple cases enable the researcher to replicate the study where the set of cases is treated as a series of experiments. Each case may confirm or disconfirm the inferences drawn (Yin, 2013). Further, it enables the study of general principles induced from the first two case studies, in action, in specific situations (Lewin, 1946). Two more cases, INDUSTRIAL B and INDUSTRIAL C, were added and investigated through participative case studies based on an action research methodology. The action research approach allowed a dual purpose of studying the internal dynamics of a practical transformation process while expanding the theoretical and scientific knowledge (Huxham and Vangen, 2003). The strategic business unit, INDUSTRIAL B was a consequence of an acquisition, and would undergo the transition from a traditional project based control model, similar to PROJECT A, into the control model developed inside INDUSTRIAL. Further, INDUSTRIAL C was a new strategic business unit, emulating the previous success of INDUSTRIAL A in a new market segment. The growth initiative included both organic growth, acquisitions, and integration of new organizational units. The new insights derived from experience and data collection of the action research, were grouped by variables developed, to facilitate comparisons and to refine propositions and principles.

**FINDINGS**

The overall findings of the empirical study and analysis of the case studies are summarized in five main categories below. For each category, aggregates of concrete observations are presented. The observations are then discussed relative to properties of natural complex systems. The main emphasis in this article is put on how the control model in the three strategic business units at INDUSTRIAL demonstrated resemblance of a natural complex hierarchy and organization, how this was distinctly different from the traditional project
control model in PROJECT A, and hence, how it affected the organizations ability to control the outcome.

Division by Functional Fitness

The principle of departmentalization was fundamentally different between the two companies. For PROJECT A, the departmentalization principle was one of competence, typical to the industry. The functional demarcation was between engineering, procurement, construction and commissioning, often referred to as EPCC. Within the main functions, one would find a reductionist based hierarchy of disciplines and departments. For example, in Engineering, there were among others, structural-, electrical-, and mechanical engineering; also including complementary disciplines as technical safety and document control. The typical delivery and output of an engineering department would be engineering documents of different detailed levels as for example a process flow diagram, process and instrument diagrams (p&id), technical queries etc. The performance of the department would be measured against the number and quality of documents delivered.

INDUSTRIAL had developed a different structure. Whereas PROJECT A could be described as competence centric, with founding capabilities based on competence disciplines (e.g. mechanical engineering), INDUSTRIAL could be described as product centric, where the founding capabilities in INDUSTRIAL were based around a product with a diverse set of competences needed to deliver in a reliable and repeatable manner. Further, sets of connected products would form systems, that perform a function on a higher aggregation level, as for example, a mud handling system. On the next level up, sets of connected systems would constitute the total solution, for example a drilling package to go on a drill ship. On the other side of the scale, below the product capability, sets of equipment would be manufactured or procured, connected and assembled to deliver the output product. I found in INDUSTRIAL, a simple, yet complex nested hierarchy, of equipment, products, packages, systems and solutions. ‘We deliver kit to the industry. It’s just that our kit come together in very large packages that work together and is governed by the same control system’, (Vice President Sales). This hierarchy shows strong resemblance to the natural complex hierarchies (Simon, 1962; Holland, 2014). It is a nested hierarchy where every unit on each level, i.e. equipment, product, system, solution, serves a function and fits a clear niche in the overall system.

Engineering does not represent any particular function in the actual physical solution. The solution was situated in the external environment of the engineering department as an instance of a system with ‘real-world’ complexity. The engineering process represented an epistemic model for control with the purpose to create this physical system. For PROJECT A, these connections were increasingly complex due to phenomenon in the external environment. For example, in search for cost efficiency, construction was situated in new, but less developed, geographical areas. In an ongoing project during the case study, construction of hull and
marine systems were performed at a Chinese yard. Cultural differences in management style, language barriers, and differences in yard’s employment practices, required a more complex relation between engineering control and construction control. As was noted by Senior Vice President of Project, ‘These drawings are complicated enough already, and then you expect a Chinese welder to understand some scribbling and comments from a Norwegian engineer?’.

Equal examples, driving increased complexity, were found in relations between projects and new requirements in HSEQ related to operations, in quality control regimes from clients in the commissioning phase, and more.

The INDUSTRIAL model was substantially different, and would provide functional fitness of its capabilities on all levels with four underlying propositions. First, a product capability in INDUSTRIAL were typically the remains, and a distilled version, of a previous product company acquired by INDUSTRIAL. The repertoire had been somewhat constrained by connections between the capability and other parts of the organization. However, the essential repertoire of a product company remained intact, including: industry and market insights; continuous innovation in technology, product features, and fabrication methods; partnerships with suppliers. The complexity stemming from patterns of interaction would be contained inside the boundaries of this product capability, and be the founding system of its existing repertoire. Second, the product would still be positioned as competitive, both in an external market, and as part of INDUSTRIAL’s systems and solutions. Hence, on one hand, its functional fitness would constantly be tested and positioned in a fitness landscape given by the supplier market. On the other hand, the ability to serve a function, to produce reliable outcome (i.e. with expected quality, on time, on budget), over time, would constitute the fitness function as a product capability in the internal fitness landscape in INDUSTRIAL. The competitive pressure on the overall solution level, and on the systems level, would lead to co-evolution of products and connections between them on a product level. Third, the complex hierarchy of the product, system and solution capabilities in INDUSTRIAL, would seek to mirror the actual functions found in the real-world solution being designed and constructed. The function of a system with its connected products in the real-world solution, would be represented in the founding capabilities of the organization. The function of the product itself was moreover clear. The interface between products were equally clear. This structure would help simplify and clarify the understanding of the connections and interfaces between the capabilities. Fourth, the product capability with its defined boundaries related to the product properties, would show resilience to the perturbations from the environment. In order for the product to remain functionally fit in the system (on the level above), any change would have to take place in a co-evolution process with other product capabilities. Challenges and perturbations from the environment, e.g. from the client, had to be compensated for, and contained, within existing structures. Any change, that is not for the greater good of the system, would reduce the systems functional fitness and create potential instability of the capability.
Structural Fitness

The case study investigation revealed that the structural fitness of the capabilities was a condition for control of the overall project. The term fitness is often used relative to the system’s environment in the meaning of performing and upholding a function. However, fitness can also relate to the state of being fit, meaning that the internal structures are fit. This may be distinguished from functional fitness, as structural fitness (Heylighen, 1999). Stronger connections between the parts of the system will increase its structural fitness. This is similar to the properties of routines and capabilities in organizational theory. A routine or a capability is a pattern of interactions that reoccur with a certain frequency. Connections and relations are based on interactions between a necessary variety of competence, systems and physicality. The connections increase in their strength by for example, the frequency of interaction, the quality of communication, and the proximity between actors.

Four different factors would contribute to how the different organizational structures, processes and underlying philosophies lead to significantly different degrees of structural fitness. First, the repeatability and frequency of projects. PROJECT A would conduct the entire project founded in a traditional competence based project organization. Each project would typically last 25-35 months, depending on scope. It was deemed imperative that the same resources holding the understanding of the project remained in the project organization as long as possible to ensure continuity and quality. The frequency of project participation would therefore be quite low relative to the individual’s career; e.g. over a 10 year period, the expected number of projects to participate in could be 3-5. As the Chief Operating Officer in PROJECT A noted, ‘I never held the same position twice in a project. I have been in this industry for almost twenty years and I have only been project manager once, then I was moved up the ladder’. On the other hand, INDUSTRIAL had in the decade between 2000 and 2010 produced 180 solutions. This provided a very different frequency, with repeatability of activities throughout an entire project. The frequency enabled stable patterns of interactions to emerge with similar resources, processes and requirements. The reoccurring stable patterns of interaction provided a higher structural fitness of the capabilities.

Second, employee integrity, turn-over and stability. In the traditional project model, external contractors were used to compensate for variations in scope and workload. Further, a competence based project organization, shows resemblance to an internal competence market, where resources naturally position and promote their profile to progress or uphold their position (Sennet, 2011). This market of supply and demand extended into similar project organizations among competitors. Resources were frequently and fluidly moving between teams, projects and organizations. In INDUSTRIAL, on the other hand, a resource would typically fill a role in a team of cross discipline competence in a product/system unit. The role was stable over a repeatable number of deliveries, providing security and integrity, leaving...
less incentives to look for other opportunities. The turnover in INDUSTRIAL was significantly lower, and stable teams developed in the product centric capabilities. The strength of the connection between complementary competences increased over time and reinforced the structural fitness.

Third, in both companies, deliverables from the projects were systematically stored. Lessons learned were extrapolated to provide insights to new projects. Insights and competence were coded into symbolic representations and stored in structures and systems. Project execution models were developed to structure the process and incorporate previous deliverables. This would act as the structural and organizational memory. The structural memory is part of the complex system of an organization. The interactions between the actors and the memory systems are a natural and vital part of developing the required complexity and structural fitness of a capability. In PROJECT A, the turnover of resources and the low frequency of project execution, lead to a weak connection between current project members and the existing structural memory. More often, new projects with new team members would dismiss previous deliverables in search for new development and optimization. The structural memory would gradually loose its function, and the weak connection between the teams and the structural memory would decrease the structural fitness of the overall capabilities. In INDUSTRIAL, on the other hand, the opposite was true. The resources would frequently interact with the structural memory. The symbolic structures were created by the same team members that would be interacting with the structured memory in the next project. The incentives to structure and store knowledge and insights were obvious as the same people would eventually execute the next project. Hence, the structural fitness of the capabilities increased with the strength of the connection between the actors and the memory structure, and the variety and strength of the memory structure itself. The systems would help structure the process and generate deliverables to the project. As a result, in INDUSTRIAL, one project manager could lead two and even three projects in parallel.

Fourth, the general complexity in the oil and gas industry has increased significantly over the last decades. This is partly due to stricter regulatory requirements, e.g. after Macondo accident, flowing down to more complex requirements from clients and governmental bodies. Further, the current development projects are also more demanding with exploration in deeper water and more difficult conditions, requiring more complex technical solutions. The market for competence, fabrication and financing had also become global and interconnected. As can be derived from the principle of requisite variety, the complexity of the project organization must reflect this increased complexity in the environment to continue to uphold its functional fitness. The internal structure must therefore develop to equally create the required variety and connections to provide the structural fitness. In PROJECT A, the functional departmentalization with a split between engineering, procurement, construction and commissioning, would require new connections between the variety of functions. As discussed in the introductory section, in a natural complex hierarchy, the systems at a higher level has a lower structural fitness than on a lower level due to the strength of the connections.
Consequentially, the connections created between engineering and fabrication on a corporate control level in PROJECT A, was weaker than the connections between engineering and fabrication inside the product centric team in INDUSTRIAL. In INDUSTRIAL, the product centric departmentalization, would already contain cross disciplinary teams, and additional variety (competence, systems and resources), and strengthening of connections, would take place inside the team. In the product centric capabilities of INDUSTRIAL, the engineering and fabrication resources would show a sense of team loyalty and belonging. Further, the teams were usually co-located within close geographic proximity, adding to the structural fitness of the capability.

_Simplified Interfaces_

The connections between parts in an organization are represented by the interaction and the interface between people, systems, routines, and capabilities. A stable connection can also be seen as a constraint to the total possible repertoire of the routine or capability. Out of the total possible (inter)actions in the repertoire, some are chosen, following Campbell’s principle of selective retention (Campbell, 1974). In a very general sense, the system itself, can be defined as the constraints that govern the variety (Heylighen, 1995).

In my investigations, I found significant differences in the two organizations. For PROJECT A, the interfaces would be found between the steps of the EPCC process, and vertically within each of the steps. This would create complex interfaces with large sets of connections horizontally and vertically. For example, the interface between engineering and fabrication could be very complex as the output of the engineering, i.e. documents and drawings, were received as the basis for activity in fabrication and construction. The full complexity of the technical solution would hence be exposed as a connection in this interface. Vertically, the interfaces between the disciplines would also be complex, due to the nature of the work, where complicated technical issues needed to be cleared out, often across different disciplines and time zones. This became increasingly complex when more than one project was conducted in a matrix organization of projects and disciplines. The interaction would be exposed to prioritization with potential time delays, and due to the complexity of the interaction, would be difficult to observe and to manage. Tasks would get ‘stuck’ in the matrix without visibility to the consequences that it might have on connected areas. The individual engineer, for example, would ‘just have too much work piling up, with different projects, different people and different demands’, whereas the project manager was left ‘chasing around trying to understand where it got stuck’.

In INDUSTRIAL, the product centric structure, would follow the physical interfaces of the product in the system, and between the systems in the overall solution. The complexity of the product engineering, procurement and fabrication would be contained and absorbed in the product capability where the structural fitness was higher; i.e. proximity, repeatable and stable.
patterns, face to face communication, etc. The project management was not exposed to, and did not try to control, this complexity. From the product centric tradition (as described above), the product attributes, hence, the product interfaces, were stable and well known in advance, and therefore reduced complexity. The complexity of constraints in the interaction would be limited to the products function with its output attributes, and the time and cost of delivery. On the systems level, products were specified, received and tested. For the critical systems, the parts were assembled and connected to test all interfaces, and to test the qualitatively different functional properties on the system level. The systems would then be shipped off to the complete integration of the total solution. Hence, the interfaces in both the horizontal and vertical dimensions were significantly simplified. The overall complexity of the solution remained the same, but the appearing natural hierarchy, simplified the control system needed to control the overall result.

Dynamic Capabilities as Metasystem Transitions

As discussed in the introductory section, emergence of a new level with new qualities may come from the system of connected parts on the level below. The new level may be static as for example a crystal that connects atoms into a new symmetric shape, or a city made up of a network of physical architecture. In most living systems, however, the new level is dynamic, with the ability to influence the activity on the level below. We may refer to this type of level as a meta level, i.e. not only does it emerge from the constraints on the variety between the parts on the level below, but it can also alter the connections and potential repertoire on the level below. This brings an interesting reciprocal dynamic between the two levels. The level above exists because of the interaction between parts on the level below, and the variation in the system below is controlled by the meta level above. The emergence of such meta level can be described as a meta level transition (Turchin, 1977). An emergent new meta level shows the same qualities as what is described as a dynamic capability in organizational and management theory (Braathen, 2018). A dynamic capability may vary the operational capabilities in an organization by altering resources, processes and interactions within and among them.

In my investigation, I found that one of the main contributions to resolve the paradox of control in the INDUSTRIAL organization was a dynamic capability that had emerged as a control mechanism. What I found as particularly interesting in my studies of INDUSTRIAL A, was that this control mechanism was not purposefully designed, nor was it constituted in a single organizational management unit, but rather distributed and inherent in the organization itself (Braathen, 2018). The dynamic capability was a meta system transition. New variety was added to the organization through an aggressive acquisition strategy, where a number of new product companies were included. ‘We wanted to become the Walmart of the oil and gas industry’ (CEO). Each product company would retain its functional and structural fitness,
however, be encouraged and requested to look for connections and synergies with other products in the organization. With increased complex demands from the environment, and the right market conditions (demanding a functional solution, unable and unwilling to specify and try to control the development), a stable pattern of interaction with repeatable deliveries would be established. A new level of systems and solutions would emerge. This new level would not only retain new properties on the system and solution level, but it would also constrain and control the repertoire, the connections, and the change and variation of them, on the product and equipment level. The overall solution would not only constrain the variety, meaning that it controlled the repertoire and output of each unit. It would also control the constraints on variation, meaning that it would control how the repertoire of the variety was ‘allowed’ to change. This would be a new type of constraints, constraining the change in variety; i.e. variation. In other words, this could be described as constraints on the constraints on variety (Heylighen, 1999). In practical terms, this would mean that each level above in the hierarchy; i.e. the solution, the systems and the products; would exist and be constituted by the constraints on variety on the level below, however, would also be regulating how, when and if the level below could vary. The solution level would control how, when and if the system level could vary; and the system level would control how, when and if the product level could vary. My findings point to the proposition that the natural hierarchy described in INDUSTRIAL, with a meta system transition as a dynamic capability, would be a key source to the emergence of a natural complex system that avoided the control paradox.

**Resilience by Vicarious Selectors**

For a natural ‘living’ complex system, it is vital that perturbations in the environment cannot act directly on the variety and connections in the system itself. A natural, but blind, selection of new variety might destroy the system. For a social system, such variety may be for example influence from beliefs shared by communicating individuals, new attempts to optimize a solution, etc. (Schaller, 2011). The evolutionary process of a social system cannot be seen as a result of cascading interactions from the lower levels, but need to be observed on multiple levels simultaneously. The knowledge of the system on the level above will seek to anticipate and regulate possible negative effects of natural selection on the level below. This phenomenon is part of the systems control, and was defined by Donald Campell as vicarious selectors. The vicarious selectors would anticipate effects from the interaction between the system and its environment, and from its anticipatory knowledge, select the best variations. Further, the vicarious selectors would seek to move the evolution of the overall system on the level above, out of an unfit position caused by selfish/local optimization (Heylighen and Campell, 1995). Campell proposed that the vicarious selectors would be an integrated part of the natural nested hierarchy, and that they among themselves, could undergo variation and selection. This would allow for a multilevel cognitive process that increases the sustainability of the system and its adaptability to changes in the environment.
In the practical context of the case studies, I found that both the external clients in the environment, and internal stakeholders in the organization, would present challenges and requests for variation and optimization. On one hand, clients wanted to impose their own standards. The oil companies have large organizations, whose sole function is to develop internal standards and philosophies, and to control its implementation. On the other hand, internal resources in the project will, with the best intentions, seek to improve and optimize design, and hence, bring new variety into the solution. Finally, suppliers and partners in the value chain will seek to influence the solution to optimize their role and function; e.g. operations will try to influence the technical solution for operations and maintenance. The introduction of such variety would often result in effects that reduced the functional and structural fitness of the overall system. ‘Operations always want to gold plate everything, if they got it their way we would never win a project’ (SVP Business Development). To remain in control over the overall solution, it was imperative that the organizations became resilient to variation requests. This is a well-known phenomenon in all project based organizations, hence, procedures are developed to control variation orders.

In PROJECT A, the entire value chain from finance, EPCC and operations, was internalized and integrated in the same organization in a complete value proposition of a lease and operate model. On one hand, the complexity would allow for opportunities to optimize the whole value chain, where for example, a well-designed system would present possibilities for cost efficiency and quality benefits in operations. However, on the other hand, the topology and sequence of the steps in the process would remain causal. Changes and variety introduced as optimization at an early stage of the process, could potentially lead to negative effects, only visible when the system was brought into operations. The well-intended optimization would more often end up with the opposite results, sub-optimizing the whole and optimizing the parts. Countless examples would show that the project control mechanism was unable to compensate for the gravity of the linear and sub-optimizing process of the EPCC in order to capture value of the optimizations. The vicarious selectors did not operate in a natural nested hierarchy, but in a sequential process given by the process divided by competence, and was not sufficiently founded and fit, in order to avoid a blind variation. For example, a client request would be promoted by the capability that defined the project with financing and business development. The variation perturbation would act directly on the project organization, and the effect would show itself in operations. As a consequence, none of the solutions in operations would show any resemblance among themselves, providing a poor basis for scale of services, resources, training, spare parts and more in operations, and therefore, reduce the controllability of the final result of the project.

In INDUSTRIAL, the role in the value chain, and the overall value creation model was less complex than the situation for PROJECT A. The function of INDUSTRIAL did not include ownership nor operations, and was purely the delivery of a solution. The boundaries between the system and its environment in the value chain were therefore clearer. The management in the nested hierarchy of products, systems and solutions acted as vicarious selectors evaluating
how requirements for change or optimization on one level might have negative effect on another. The clarity of boundaries on the products level, on the systems level, and on the solution level, would enable a hierarchy of vicarious selectors on multiple levels to accommodate adaptability through a multilevel evolution and cognitive structure. The structure would coordinate adaptability to new requirements and complexity in the environment.

This would also result in resilience on the solution level towards attempts of outside influence. The management could take part as vicarious selectors in evaluating different client standards and requests, and vicariously evaluate and select the changes in order to understand the impact on the overall system. More often, the request from oil companies to comply with their standards would be declined. According to senior management in INDUSTRIAL, this would cost them a number of contracts and projects with the larger oil companies that were unwilling to procure a solution comprised of functional products, but rather wanted to specify and control the solution according to their own specifications and standards. My findings indicate that the senior management’s role as vicarious selectors, providing resilience to change, most likely contributed significantly to the success of INDUSTRIAL.

DISCUSSION

The categories in my findings were crafted from the comparative study of the two organizations PROJECT A and INDUSTRIAL A with significantly different project execution models. Both organizations had a track record of multiple projects and solutions delivered. For INDUSTRIAL B and INDUSTRIAL C this was different. INDUSTRIAL B was acquired by INDUSTRIAL, and had up to that point operated under a traditional competence centric project model similar to PROJECT A. INDUSTRIAL B started a transition into a control model inspired by INDUSTRIAL A. INDUSTRIAL C, on the other hand, was a new business unit under development, based on both organic growth and acquisitions. The transitional perspective in both INDUSTRIAL B and INDUSTRIAL C created different challenges that would open up for further questions to be investigated.

In short, the structure and success of INDUSTRIAL A was a result of three evolutionary and systemic occurrences, that were different for INDUSTRIAL B and INDUSTRIAL C. First, a series of product company acquisitions, provided the right variety. Second, the connection between technology and products formed packages with a new function, and a new value proposition to the market. Third, the emergence and metasystem transition of an overall solution, based on a variety of connected systems (packages). The environment that would determine the functional fitness of the overall solution was a fourth determining factor. The market was entering a new cycle for oil and gas, with higher energy prices, and in a race for exploration and production of offshore oil. Concurrently, the supplier industry struggled to deliver solutions that were on time and on budget, and that were reliable in operations in order
to enable economy of scale for the operator. This market situation led the clients to willingly, give up their own internal technical specifications and control, and rather buy solutions based on functional specifications. The letting go of control, provided the opportunity for repeatability, leading to predictability in the project execution process, and reliability from robust solutions in operations. The increased pressure for innovation from the environment (market), combined with evolution of structural and functional fitness in the product capabilities, initiated processes of coevolution among the product capabilities. The emergence of a solution level in this environment was a metasystem transition that effectively established a dynamic capability where the control model was inherent and distributed in the overall system. The efficiency and effect of this natural control model lead to a substantially higher functional fitness on the overall level, compared to the traditional project execution model.

The transition of INDUSTRIAL B and C was not a natural evolution, but rather a conscious management of the structure and process, emulating the system of INDUSTRIAL A. INDUSTRIAL B had realized that the matrix organization would lead to complexity that was difficult to control when volume increased. The market was highly cyclical. The project execution model would remain in control of the projects when the market was low, and the total focus of the organization was set on a particular project. When the market grew, the number of projects and workload would increase accordingly. The complexity increased exponentially and would lead to major time delays, with consequential cost and schedule overruns. Historically, it had been a negative correlation between volume and profit throughout several market cycles.

Three main challenges appeared that relate to the categories in my findings above. First, in INDUSTRIAL B the transition into a new model would require a restructuring from a competence based matrix organization following the EPC process, to a system centric organization, centered around cross discipline delivery teams of sub-systems to the overall solution. Each sub-system would again comprise multiple products to be combined. The transition would require letting go of existing control structures in the traditional project plan, and let the new teams ‘self-organize’ in order to optimally deliver their output in a reliable and repeatable manner. Further, the reporting philosophy was turned from extensive reporting to ‘negative reporting’, i.e. minimum reporting only regarding the overall deliverable, the interface with other sub-systems, and any deviation from the original plan. The project management’s focus went from control of the activities in the project, to the control of interfaces, the sub-system deliverables, and focus on the client management of expectations to actively compensate for perturbations. Hence, the project management and management of the delivery teams started to act as a system of vicarious selectors in order to maintain resilience of the system, rather than acting as controller of action.

The senior management of INDUSTRIAL B would experience significant resistance from both team members and the project management. First, the team members experienced a lack of control as the detailed project plan was replaced with a new control model, and the team
needed to coordinate itself between disciplines of engineering, procurement, fabrication and support functions. There was a sense of letting go of control. As noted by one of the team members, ‘…this is going to be total chaos, we are breaking down everything that we have built up over years’. The underlying understanding of what it meant to be in control was strongly embedded in the belief systems, and the changes made, were counterintuitive and paradoxical. Second, the project management experienced a similar lack of control, not controlling the activities inside the capabilities delivering the sub-systems. Further, the significance of the project manager role was perceived to be reduced. ‘I don’t see the point in being a project manager anymore. I feel like I have lost all control and my role has diminished’. The fitness landscapes needed to be adjusted based on the functions and the overall deliverables. The function of the project manager was turning to an increased focus on being a vicarious selector rather than a controller of activity. Third, the repeatability would lead to standardization and structural memory (as was intended), but would also lead to resistance from the most competent people in technology and engineering. ‘You know how boring this will become? Churning out the same work over and over again?’ (technical subject matter expert). The structural fitness of the capability would increase with the stability from repeatability, and the increase in strength of the organizational memory of the structures, standards and systems. New roles for innovation and technology development were opened to accommodate this. In spite of these transitional organizational and individual challenges, the new control model demonstrated to be more effective. INDUSTRIAL B would in a 3-year period both double its volume and double its profit, and hence, escape the negative correlation between volume and profit. This effect could obviously also be subscribed to other factors, as for example better risk management, optimal pricing strategy, etc, however, the control model did demonstrate its ability to deliver high volume of large scale complex projects on time, on budget, with the right quality.

Also in INDUSTRIAL C, challenges appeared in the buildup transition phase. The naturally evolved hierarchy of INDUSTRIAL A would be characterized by the functional and structural fitness of each capability on each emergent level. When designing and developing the overall structure of INDUSTRIAL C, a similar structure was desirable. INDUSTRIAL C would base its nested hierarchy on, existing capabilities found in INDUSTRIAL A; acquired product and systems companies assimilated into the INDUSTRIAL structure; and organic growth of new capabilities in INDUSTRIAL C. The challenge appeared to be the vertical structural fitness and the temporal functional fitness of the overall solution/organization. First, the business development to the end customer would require an internal temporal coordination. This coordination required an overall fitness landscape, where each capability would renew their understanding of fitness from the existing visibility in an external market, or as part of for example INDUSTRIAL A existing solution structures, to a new fitness function in the buildup of INDUSTRIAL C. In practical terms, this would appear as ability (potential failure) to prioritize resources and bidding budgets to offer solutions to new internal opportunities in INDUSTRIAL C. Second, the initiative in INDUSTRIAL C intended to ‘leap frog’ the
coevolution of the emergent levels of products into systems, and systems into solution; and rather go directly to a solution that also comprised the three levels. The individual sub-systems had not been through a repeatable delivery cycle with optimizations of the interfaces and of the systems themselves. The repertoire of each capability was less constrained, and this increased the internal complexity while reducing the overall structural fitness. As was noted by senior vice president of corporate sales and marketing of INDUSTRIAL A, while discussing the early development of some of the subsystems in INDUSTRIAL A, ‘…you know, we had delivered the system multiple times, the clients looked upon us as best in class. We already had the traction and the history’. As my research in INDUSTRIAL came to an end, INDUSTRIAL C had yet not delivered a full solution based on the designed natural hierarchy. It remains to be seen whether INDUSTRIAL C can accelerate the evolution of its structural fitness.

One of the practical limitations to the natural complex system control model became apparent during my longitudinal study across the four cases. There was a sharp drop in oil price in 2014 of about 70% at its peak. This resulted in an equally radical reduction in activity and new orders for the organizations involved. The structure implemented in INDUSTRIAL A and B, had demonstrated superior performance in an upturn market cycle, but would also include redundancy and appear to be too costly in a market with low activity. The overall structure had reduced complexity through constrained variety and simplified interfaces. However, the constrained variety would also create inflexibility in a market that did not value the scale and capacity that had been developed. Lack of new orders, smaller projects, prolonged business cycles including more studies and FEED engineering, would challenge the structure and demand an increase in internal complexity. The external fitness landscape had changed from one with clarity on traditional properties as cost, time and quality, to one that included more local optimums, influenced by for example, internal reorganization processes in oil companies, politics around shareholder’s demand for dividends, global policy on oil price by OPEC, etc. This would increase the complexity in the market and challenge the internal structures to increase flexibility and complexity. Part of the structures established in INDUSTRIAL B would be forced back to a more traditional project model in order to meet the demands for flexibility.

**SUMMARY**

The present paper has proposed that properties found in control models of natural complex systems can be applied to resolve what we experience as a paradox of control. The paradox of control is a social paradox characterized as a learning paradox where the cognitive structures of a social system is unable to interpret and process increased external complexity.

The paradox is apparent in many fundamental functions of society, as for example health care, education, and research, struggling to find effective control models to deliver the adequate
results. We can also find the paradox of control in large scale industrial mega projects, where I chose to situate my investigation. The findings support the hypothesis that the paradox of control, comes from multiple sources that originates in our fundamental belief system underlying our design of control models. These belief systems are remains from our heritage of reductionism and positivism. Our mental frames incline us to design control models that unconsciously and inadequately introduce complexity, and leads to complicated decision making, long response time and time delays. Yet, on the other hand, underestimate the complexity of the challenge in the environment, and seek to apply control models that are too simplistic, based on a reductionist departmentalization, without sufficient attention to the connections, interfaces and boundaries.

I was basing my investigation in two organizations, and four cases, with different control models and accompanying organizational structures. Five, categories were derived that I claim could significantly influence current control paradigms, and potentially eliminate the learning paradox. First, a functional fitness centric model emulating a natural complex hierarchy with nested levels of capabilities based on equipment, products, systems and solutions, as opposed to a departmentalization based on reductionist thinking. The structure would optimize functional fitness in the organization’s capabilities, while reducing the complexity of the interfaces between the different units. Second, the ability to create structural fitness in routines and capabilities by focusing on connections between actors. Determining factors were focus on relations, interactions between individuals, repeatability and stable patterns, but also a continuous development of structures through action, systems and structures as organizational memory, and the interactions between them. Third, reduction of control complexity from the ability to control the properties at the right level and reduce complexity of the interfaces. The qualitative properties are different at different levels in a natural complex hierarchy, and the purpose of control changes from focus on the activity on the level below, to the output and interfaces on the level above. This reduces the complexity, and increases the ability to observe and control. Fourth, the natural complexity of a system may lead to meta system transitions that incorporate the same qualities as a dynamic capability. This dynamic capability can control and alter the operational capabilities on the level below; i.e. variation in the repertoire, meaning a variation of the variety and connections on the level below. The dynamic capability may be inherent and distributed as supported by my findings in the case study of INDUSTRIAL A, or may be designed and managed as supported by my findings in INDUSTRIAL B. Fifth, the role of managerial structures acting as a system of vicarious selectors. In a natural complex social hierarchy, the level above will act as vicarious selectors to reduce blind variety and increase the resilience of its structure and function. The vicarious selectors on multiple levels will ensure a coordinated adaptability and sustainable coevolution inside the structure. Hence, the vicarious selectors enable resilience to unwanted perturbation from the environment.

Our hyper competitive and dynamic environment is in a constant evolution from a complexification process. This will continue to challenge our organizations and institutions,
and will invoke an increasing number of paradoxical experiences, felt both on an organizational and an individual level. I have argued that new principles informed by natural complex systems should be derived and applied to organizational control models. I hope that practitioners may find inspiration in the translation of the practical experiences from the case studies into theoretical distinct concepts, in order to support them in management and navigation in real-life organizations.


Gable, Guy. n.d. “Integrating case study and survey research methods: an example in information systems”


Stansbury, Jason, and Bruce Barry. 2007. “Ethics Programs and the Paradox of Control.” Business Ethics Quarterly 17 (2): 239–61


